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Truthing and Preliminary Clutter Analysis for a Multi-temporal Synthetic Aperture Radar Data Set

M. Yeremy
Defence Research Establishment Ottawa

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

TECHNICAL MEMORANDUM
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M. Yeremy
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ABSTRACT

A collection of Radarsat images over CFB Gagetown, New Brunswick has been collected from mid-1996 until early 1998, for the purposes of studying multi-temporal backscatter behaviour. This is relevant for the classification of clutter and for applications like target detection and surveillance. It is well documented that for different environmental conditions (such as degree of foliation and moisture levels) the backscatter can vary substantially. This technical report is the first in a set of two. In this report, ground truthing results and preliminary analysis results are documented while in the next report, a more detailed analysis will be presented.

The ground truthing documented here was provided by two sources; CFB Gagetown and DREO. CFB Gagetown provided ground truthing of the base while many of the image acquisitions occurred. DREO conducted an extensive ground truthing effort for stationary sites on the base in the fall of 1997.

The analysis of this data will concentrate on clutter and target backscatter behaviour with reference to the statistical and physical characteristics. In this report, a preliminary analysis of two images is also presented. These images were chosen so that two extreme environmental conditions are represented. One image is from the summer when the foliage is well developed while the other image is from the spring when snow is still on the ground and some thawing processes have commenced.

Most of the clutter results determined for this report correspond very well with the clutter backscatter coefficients found in the literature. The variability of backscatter with seasons and precipitation was found to have a large dynamic range for some clutter types or scenarios.

In many cases, it was impossible to distinguish the targets from the clutter, particularly since the resolution cell of Radarsat images is often larger than most targets. For future studies like this it is advised that the data be accurately georeferenced in order to evaluate the backscatter from small targets. The imagery of CFB Gagetown and surrounding area is a particularly difficult area to georeference, since there are not very many man-made ground control points visible in the imagery (e.g.; such as road intersections) and much of the land is not developed.

The environmental backscatter results and variability were often similar to other values found in the scientific literature. Target backscatter results found here are not reliable because it was difficult to identify targets due to inadequate image resolution cell sizes and variable environmental background backscatter characteristics.

RÉSUMÉ

Radarsat a pris une série d'images au-dessus de la BFC de Gagetown, au Nouveau-Brunswick, de la mi-1996 jusqu'au début de 1998, afin d'étudier le phénomène de rétrodiffusion pluri-temporel. Ces images sont nécessaires à la classification du fouillis et à des applications comme la détection et la surveillance. On sait que pour des conditions environnementales différentes (la massed foliaire le degré de foliation et le taux d'humidité) la rétrodiffusion peut varier passablement. Ce document, le premier de deux rapports techniques, décrit les résultats de vérification au sol et d'analyse préliminaire, tandis que l'autre rapport présentera une analyse plus détaillée.

Les résultats de vérification au sol examinés dans le présent document proviennent de la BFC de Gagetown et du CRDO. La BFC de Gagetown a fourni la vérification au sol de la base lors de la prise de nombreuses images, tandis que le CRDO a réalisé une vaste vérification au sol des sites fixes de la base au cours de l'automne 1997.

L'analyse des données se concentrera sur le fouillis et le phénomène de rétrodiffusion de cible par rapport aux caractéristiques statistiques et physiques. Ce rapport présente également une analyse préliminaire de deux images illustrant deux conditions environnementales extrêmes. L'une a été prise en été, quand le feuillage était bien développé, l'autre au printemps, quand il y avait encore de la neige au sol et que le dégel était commencé.

La plupart des résultats concernant le fouillis contenus dans ce rapport correspondent très bien aux coefficients de rétrodiffusion de fouillis mentionnés dans la documentation. On a constaté que la variabilité de la rétrodiffusion, selon les saisons et les précipitations, présente une vaste plage dynamique pour certains types de fouillis ou scénarios.

Dans bien des cas, il a été impossible de distinguer les cibles du fouillis, notamment parce que la résolution des images de Radarsat est souvent plus grande que la plupart des cibles. Pour les études ultérieures de ce genre, il serait bon de géocoder avec précision les données afin d'évaluer la rétrodiffusion de petites cibles.

Les résultats et la variabilité de la rétrodiffusion environnementale ressemblaient souvent aux valeurs que l'on trouve dans la documentation scientifique. Les résultats de la rétrodiffusion de cible obtenus dans ce cas-ci ne sont pas fiables en raison de la difficulté à déterminer les cibles causées par la taille inadéquate de la cellule de résolution des images et de la variabilité de la rétrodiffusion environnementale.

EXECUTIVE SUMMARY

Radarsat is a Synthetic Aperture Radar (SAR) satellite, which provides a surveillance capability regardless of weather or daylight conditions. The satellite has an average repeat pass time of about 3 days at 42° latitude and an exact repeat pass time of about 24 days. The Radarsat product has the advantage that several beam types are dynamically available. A limiting factor of Radarsat is that the best possible resolution available is about 7.8 m, which implies the requirement for some image interpretation. Radarsat has only one polarimetric channel (HH) which can also be a limiting factor for some clutter types.

It is only within the past 5 years, largely due to the commercial availability of imagery, that environmental researchers have used imagery extensively for monitoring the environment. Imagery interpretation of water-covered and ice-covered regions is mature while land clutter is more complex, predominantly because of the variability of terrain and land cover. For SAR imagery, unless adequate topographical databases are available, misleading interpretations can result from terrain variations because corrections must be made for geographic coordinates and the incidence angle. For this and a following report, land clutter for a northern temperate climate (CFB Gagetown, New Brunswick, Canada) will be studied. This report will emphasize the ground truthing and preliminary analysis, while the final report will provide detailed multi-temporal backscatter estimates for various types of land clutter and targets.

The goal of this investigation is to develop imagery-based identification tools for land clutter classification using the Radarsat sensor. This information can then be used for data exploitation purposes to reconstruct sites from the imagery as well as provide a data base of multi-temporal target and clutter behaviour for the Radarsat sensor parameters. Areas emphasized in this study include; marshland, forests, grasslands, infrastructures and man-made targets. The results from this study can be used for the following applications; target detection in clutter, surveillance of an environment, site reconstruction from images, trafficability assessment, disaster management, change detection and site monitoring.

A brief outline of the preliminary results follow. Land target backscatter estimates are difficult to obtain from Radarsat imagery since most land target dimensions are of the same order as the image resolution cell. Also, the target clutter was not particularly distinct compared to many types of environmental clutter. There are many examples where the environmental backscatter values are larger than the target backscatter values, which indicates the requirement for smaller resolution cells and more information (e.g.; fully polarimetric or multi-frequency imagery) before one can properly classify targets in SAR imagery. For this study, it was difficult to identify the targets in the imagery, without accurate geo-referencing capability. In contrast, Radarsat imagery is suitable for determining environmental backscatter values, particularly if the area of analysis is large relative to the resolution cell size. The environmental clutter results found here are, in most cases, very similar to values found in the scientific literature and vary with seasonal foliage and precipitation characteristics. Although most studies emphasize the statistics of large

environmental regions, it should be noted that attention to the environmental variability may be tactically useful for applications such as; trafficability, surveillance of natural and man-made disasters and changes in the environment.

TABLE OF CONTENTS

Page

ABSTRACT iii
EXECUTIVE SUMMARY vii
TABLE OF CONTENTS ix
LIST OF FIGURES xi
LIST OF TABLES xiii
1. INTRODUCTION 1
2. ENVIRONMENT OF CFB GAGETOWN 3
2.1 General Description of the Environment 3
2.2 Environmental Data Sources 5
2.2.1 Environmental Ground-Based Measurements 6
2.2.2 Geomatic Data 7
3. RADARSAT IMAGERY DATA AND GROUND-TRUTHING BY CFB GAGETOWN PERSONNEL 8
4. GROUND-TRUTHING BY DREO OF QUASI-STATIONARY TARGETS AND ENVIRONMENTS 10
4.1 List of Areas Investigated 10
5. PRELIMINARY DATA ANALYSIS 13
5.1. Data Analysis 13
5.2. Clutter Results 14
5.2.1 Airstrips and Airplanes 15
5.2.2 Marshland 17
5.2.3 Grassland 19
5.2.4 Red Pine Forest 21
5.2.5 Gas Tanks at Camp Petersville 21
5.2.6 Gravel Parking Lot 22
5.3. Error Sources of Backscatter Estimates 23
6. DISCUSSION AND CONCLUSION 26
Appendix A CFB GAGETOWN GROUND TRUTHING AND DATA 28
A.1 METEOROLOGICAL STATIONS AT CFB GAGETOWN 28
A.2 GROUND TRUTHING COINCIDENT WITH AN IMAGE 35
Appendix B DREO GROUND TRUTH LOG 46
Appendix C DREO GROUND TRUTHING 54
Appendix D PHOTOGRAPHS 104
D.1 Air Photograph Documentation 104
D.2 Land Photographs 110
D.3 Photographs 111
REFERENCES 246
ACKNOWLEDGEMENTS 247
LIST OF ACRONYMS AND ABBREVIATIONS 248

LIST OF FIGURES

Page

Figure 1. Oromocto and CFB Gagetown Headquarters. 6
Figure 2. Soil Moisture and Precipitation at Station 7a (07/96-12/96) 29
Figure 3. Soil Moisture and Precipitation at Station 7a (01/97-06/97) 29
Figure 4. Soil Moisture and Precipitation at Station 7a (07/97-10/97) 30
Figure 5. Soil Moisture and Precipitation at Station 7b (07/96-12/96). 30
Figure 6. Soil Moisture and Precipitation at Station 7b (01/97-06/97) . 31
Figure 7. Soil Moisture and Precipitation at Station 7b (07/97-10/97) 31
Figure 8. Soil Moisture and Precipitation at Station 4a (07/96-12/96) 32
Figure 9. Soil Moisture and Precipitation at Station 4a (01/97-06/97) 32
Figure 10. Soil Moisture and Precipitation at Station 4a (07/97-10/97). 33
Figure 11. Soil Moisture and Precipitation at Station 4b (07/96-12/96) . 33
Figure 12. Soil Moisture and Precipitation at Station 4b (01/97-06/97) 34
Figure 13. Soil Moisture and Precipitation at Station 4b (07/97-10/97) 34
Figure 14. Spruce stands (ground truthed in October 3, 1997 log). 51
Figure 15 Meteorological Station 4 and Surrounding Environment 52
Figure 16. Company Defensive Position Layout 57
Figure 17. Targets at the Company Defensive Position. 58
Figure 18. Bunker and Mortar Pit at Company Defensive Position. 59
Figure 19. Command Post at Company Defensive Position. 60
Figure 20. Bunker details at Rockwell Demolition 63
Figure 21. Environment and Tower at Knowlton Hill. 66
Figure 22. Close-up of Tower at Knowlton Hill. 67
Figure 23. Cemetery on Knowlton Hill. 67
Figure 24. Depiction of Stone Quarry. 69
Figure 25. Meadow and Marshland 71
Figure 26. Overview of Airstrip 1 and Region. 74
Figure 27. Details of Airstrip 1 . 75
Figure 28. Austere Village, Survey Drawing. 78
Figure 29. Austere Village, Sketch 79
Figure 30. Cemetery and the Castle Range. 81
Figure 31. Layout of Camp Petersville . 84
Figure 32. Close-up of Propane Tanks at Camp Petersville . 85
Figure 33. Close up of Fenced area at Camp Petersville . 86
Figure 34. Blissville airstrip. 88
Figure 35. Pine Forests . 91
Figure 36. Forest Fire Planes at Fredericton Airport. 94
Figure 37. Gravel and/or Sand Pits . 98
Figure 38. December 11, 1996 Site 101
Figure 39. Transformer in Oromocto. 103

LIST OF TABLES

Page

Table 1. Radarsat imagery data of Gagetown, NB with reference to truthing availability..... 8
Table 2. Summer backscatter statistics for airstrips at CFB Gagetown..... 16
Table 3. Spring time backscatter coefficient statistics for airstrips at CFB Gagetown..... 16
Table 4. Backscatter coefficient estimates from fire planes at the Fredericton Airport..... 17
Table 5. Backscatter estimates for marshland on August 8, 1997..... 18
Table 6. Backscatter estimates for marshland on March 12, 1998..... 19
Table 7. Backscatter estimates for the grassland regions in Enniskillen on August 8, 1997. 20
Table 8. Backscatter estimates for the Enniskillen area on March 12, 1998..... 20
Table 9. Backscatter estimates for a pine forest on August 8, 1997 and March 12, 1998..... 21
Table 10. Backscatter estimates of the large gas tanks at Camp Petersville, for August 8, 1997 and March 12, 1998..... 22
Table 11. Backscatter estimates of the parking lot at Camp Petersville for August 8, 1997 and March 12, 1998..... 23
Table 12 Ground Truthed Targets for Radarsat Image: May 9, 1996..... 36
Table 13. Ground truthed targets for May 16, 1996..... 39
Table 14. Ground truthed targets and features for December 11, 1996..... 43
Table 15. Ground truthed targets and features for February 16, 1998..... 45
Table 16. Ground truthed targets at the Company Defensive Position..... 56
Table 17. GPS Measurements at Site 1, the Company Defensive Position..... 57
Table 18. Ground truthed Targets and Region at Rockwell Demolition..... 62
Table 19. GPS positions at site 2. See Table 22 and Figure 20..... 62
Table 20. Ground truthed targets and features at Knowlton Hill..... 65
Table 21. GPS positions at site 3, Knowlton Hill..... 65
Table 22. Ground truthed targets at the Stone Quarry..... 68
Table 23. Ground truthed regional information of the heath along Drummond Road..... 70
Table 24. GPS positions for the bog and forest stands at site 5..... 71
Table 25. Ground truthed targets at Airstrip 1..... 73
Table 26. GPS positions for site 6, Airstrip 1..... 74
Table 27. Ground truthed targets at the Austere Village..... 77
Table 28. GPS positions at site 7, the Austere village..... 77
Table 29. Ground truthed targets at site 8, the Cemetery and the Castle range..... 80
Table 30. The GPS positions for site 8, the cemetery and Castle Range..... 81
Table 31. Ground truthed targets at Camp Petersville..... 83
Table 32. The GPS measurements recorded at site 9, Camp Petersville..... 84
Table 33. Ground truthed targets at Blissville Airport..... 87
Table 34. Ground truthing of the pine forests found along Highway 660..... 90
Table 35. Ground truthed forest fire planes on the tarmac at the Fredericton Airport..... 93
Table 36. GPS positions for site 12, the forest fire planes at Fredericton Airport..... 94
Table 37. Ground truthed display vehicles at CFB Gagetown's Headquarters..... 95
Table 38. The GPS measurements for site 13, the display military vehicles..... 95
Table 39. Ground truthed sand and gravel pit..... 97
Table 40. GPS measurements for Site 14, the gravel and sand pits..... 97

Table 41. Ground truthed environmental data at the December 11, 1996 site..... 100
Table 42. GPS positions at December 11, 1996 battle exercise site..... 100
Table 43. Ground truthed information of the transformer at Oromocto.. 102
Table 44. GPS position at the transformer station at Oromocto..... 103

1. INTRODUCTION

Radarsat is a Synthetic Aperture Radar (SAR) that transmits and receives in the C band with horizontal polarization, from a satellite platform. Radarsat was developed by Canadian industry and research institutions under the direction of the Canadian Space Agency (CSA) with design specifications for monitoring ice conditions and movement. However, since its deployment, the images from this satellite have been used for many other applications. Radarsat follows a sun-synchronous polar orbit with a mean revisit time of about 2.7 days at 42° latitude. The resolution of the Radarsat images is a limiting factor for some applications such as the detection of small targets. However, Radarsat is a suitable imagery source for surveillance scenarios since, regardless of cloud cover or lack of visible light, the C-band can discern features on the earth. Another advantage of the Radarsat design is that options like look angle and beam width can be dynamically selected prior to acquiring an image frame. Further information about the Radarsat options can be found in [1].

In this report, we will document and discuss an experiment which was designed for the following purpose; to characterize and classify imagery features under varying environmental conditions, for both target and environment clutter sources using Radarsat imagery. This experiment is the outcome of initiatives originating from the Directorate for Space Development (D SpaceD) and J2 Geomatics, both of the Department of Defence (DND), Canada.

The area designated for this experiment was Canadian Forces Base (CFB) Gagetown, New Brunswick, Canada. The experiment plan was to collect Radarsat images of CFB Gagetown for different environment conditions. Within the base limits, are a collage of mini-environments which vary dramatically in terms of vegetation, topography, climate and man-made infrastructures. In co-operation with D SpaceD and J2 Geomatics initiatives, personnel from CFB Gagetown assisted this experiment by conducting ground-truthing exercises during the time that satellite images were being recorded. Since April 6, 1996, the Defence Research Establishment Ottawa (DREO) has collected images of CFB Gagetown and coincident ground-truthed information from CFB Gagetown (when available), in order to represent all seasons and various different environmental conditions. Consequently, the results from this study will contribute to further understanding of the relationship between backscatter and environmental changes.

CFB Gagetown, New Brunswick, Canada has on-site the largest combat training school in Canada. The base is about 40 km by 50 km and has varying terrain and environmental conditions which are monitored and studied extensively by several environmental professionals. The training school conducts many combat exercises in typical combat scenes with various operational vehicles. Therefore, CFB Gagetown is an optimal environment to study Radarsat images because not only does the base provide scenes with targets of interest in typical battle-type configurations, but, it has an environmental database which can provide background evidence in support of the ensuing results.

In order to further validate the CFB Gagetown images, a ground truthing exercise was conducted by DREO in the autumn of 1997 (Sep 30 to Oct 3) with emphasis on stationary objects. The ground-truthing exercise was not a complete study, since CFB Gagetown is a vast region with many inaccessible areas. However, during this ground-truthing exercise, a selection of targets and environments were examined. In this report, the ground truthing for the stationary (conducted by DREO in autumn, 1997) and the temporal (conducted by CFB Gagetown whenever a Radarsat image was collected) targets at this base are documented, as well as a compilation of relevant environmental information.

This report is organized in the following manner. Following this introduction, the second section will give details about the environment of CFB Gagetown. In the third section, the collection of CFB Gagetown Radarsat images is documented with reference to the ground-truth records corresponding in time with these images and provided by the CFB Gagetown personnel. In the fourth section, the ground-truthing performed by DREO during the week between September 29, 1997 and October 3, 1997 are elaborated upon. In particular, details about sites investigated during that week are provided. In the fifth section, an analysis from two images for a variety of target and environmental clutter types is documented. In particular, the back-scatter reflection coefficient (otherwise known as the Radar Cross-Section (RCS) per unit area) and Target to Clutter (TCR) estimates and their statistics are calculated and documented. RCS estimates provide a measure of the reflected power from different surfaces while the TCR is essentially a ratio measure between the target and background reflected power. Finally, the sixth section will discuss the results and conclusions based on the preliminary results found in section five.

Photographs throughout this report are organized in Appendix D. They are referenced by one of two possible reference numbering systems; (1) DREO photograph number, or (2) digital images referenced by the date and photograph number. Appendix D also includes ortho-rectified aerial photographs of general regions at the base.

2. ENVIRONMENT OF CFB GAGETOWN

In this section, an overview of the environment at CFB Gagetown is documented. General descriptions of the geology, hydrology, terrain, forestry, and man-made infrastructures are provided. This will be followed by a list of various environmental data sources used for this analysis. This includes meteorological data, soil moisture data, maps and other environmental data.

It should be noted that the landscape at CFB Gagetown has and still is being altered. For instance, within the past 5 years, much of the base has been deforested. Additionally, several man-made topographical changes have occurred where new military exercise sites have been constructed. For the analysis in this report, if there was any doubt regarding any environmental feature in an image, the professionals and offices acknowledged in this report were contacted for verification.

2.1 General Description of the Environment

CFB Gagetown is located in the interior of New Brunswick about 25 km east of Fredericton. Below follows general descriptions of the environment at CFB Gagetown.

Weather

CFB Gagetown experiences all 4 seasons from moderately warm summers to cold temperatures and large snowfalls in the winter. The mean January and July minimum and maximum temperatures are respectively, -15 and -4° C and 13 and 26°C. Yearly precipitation averages are approximately 1000 mm a year with 200 to 300 cm of snow during the winter months, and rainfall mostly in the summer season.

Terrain

The terrain ranges from flat river flood plains to moderately high mountain ranges. Farming valleys, bogs, sand bars and vast marsh lands are couched near the rivers. The base is surrounded by rivers on three sides; the north, east and west. The St. John River flows north and east of the base while the Oromocto River flows west of the base. Towards the south, the hills become progressively larger and eventually approach mountain status. Interwoven amongst the mountains and hills are many rivers and lakes.

Geology

The geology of CFB Gagetown is divided roughly into two types. The northern half is of a sedimentary nature and is mostly red to grey sandstone, conglomerate and

siltstone. The southern half of the base alternates between the matrix found in the northern half with volcanic rock and metamorphosed bands in between. This corresponds with the terrain becoming progressively more mountainous with distance in a southerly direction.

Soils

The soils in the northern half of the base are mostly inorganic silt and clay soils with fine sand and occasionally gravel. This is interwoven with pockets of gravel-sand-silt mixtures. In contrast, the southern portion of the base's soil content is mostly silty gravel (sandy sometimes) with rocky outcrops increasing towards the south where the mountains occur more frequently. The soil in the northeast corner of the base has sandy regions as found from the sand spits and the sandy quarry site off of Highway 102 near Gagetown, NB. These regions are pocketed between more clay based and organic soils as well as gravelly soil types. Other sandy regions are found located by the west side of the base near Eniskillen and Hoyt, NB and near major rivers (e.g.; Oromocto River and its branches, Neremis River). There are several marshy areas near many of the rivers and lakes found on the base where peat and organic clay soil types abound.

It should be noted that throughout the base, there are areas of mineral soil where nothing grows. These generally occur in firing areas where live ammunition is regularly deployed, and are sites where out-of-control fires burned the soil to the extent that all organic material was destroyed.

Vegetation

The vegetation at the base ranges from marshy bogs and heaths near the river systems, grasslands where the organic soils exist (often adjacent to these boggy areas) and forested areas throughout the base. Predominant forested areas at CFB Gagetown are of a mixed forest type. In boggy areas, black spruce are commonly found. There are some white pine and red pine stands in the region as well as some planted and Commercially Thinned (CT) red pine stands. Also, CT deciduous forested areas are located in the base interior.

Prior to when the base was created and developed (late 1940s), the region was covered with forests and farms. The northern part of the base was initially cleared for developing exercise areas. Recently, new areas in the mid-region of the base have been deforested for future battle exercise regions. Most of this deforestation was completed during 1996 and 1997 and will likely continue into the 1998-1999 time frame. The deforested sites consist of two types; cleared sites, and grubbed sites. Clear-cut areas are areas where the forest has been totally removed, except for the remaining wood stumps and slash. The grubbed sites are cleared more thoroughly so these stumps and forest residue are removed. In particular, at grubbed sites, the topsoil, trunks and roots have been bulldozed and covered with the mineral soil, which results in a bare, rough soil. According to CFB Gagetown Forestry, it generally takes about 5 years before the grubbed areas have vegetation cover (shrubs and grass) again.

It should also be noted that there was an immense, unmanageable fire in 1986 which extended from St. John River by Coys Lake, Harts Lake, and Coytown to the original site near the Rockwell Wood North.

Another feature to note is that at the boundaries of each of the impact zones are 30 m wide borders which are bare soil to grass-covered and they are maintained with herbicidal treatments. These strips and adjacent roadways serve as fire breaks and access areas. Also, for further reduction of fire hazards, the training areas are generally grass-covered areas only and are generally areas which were grubbed many years ago.

Marshland

Another interesting facet about this area is that Ducks Unlimited Canada has developed the marshland in the immediate region for duck habitats. Many of the marshy islands and boggy areas here have been mowed (by what is called a "cookie-cutter") to create channels with preferably many corners in which ducks can hide from predators (see photographs 97-1864, 97-1907). These channel corners act as corner reflectors to the radar, producing very large backscatter returns.

Urban areas

In Figure 1 is a map of the Oromocto town site and the adjacent CFB Gagetown headquarters which are located at the outer north-west edge of the base. These urban areas are commonly found in the imagery collected for this study.

Cultural characteristics of the region

Below are documented certain distinct features of the region. There are several small graveyards throughout the base which are maintained by the base. Another interesting characteristic found at some former homestead areas, are boulder piles located throughout the open fields. Many of the farm houses in the surrounding area have steep sloped metal roofs.

2.2 Environmental Data Sources

For this report we used various information sources which varied from meteorological data to geomatic information. Below is documentation about some of the data and information which is and will be used for this study. This subsection will be further subdivided into two categories; environmental and geomatic information.

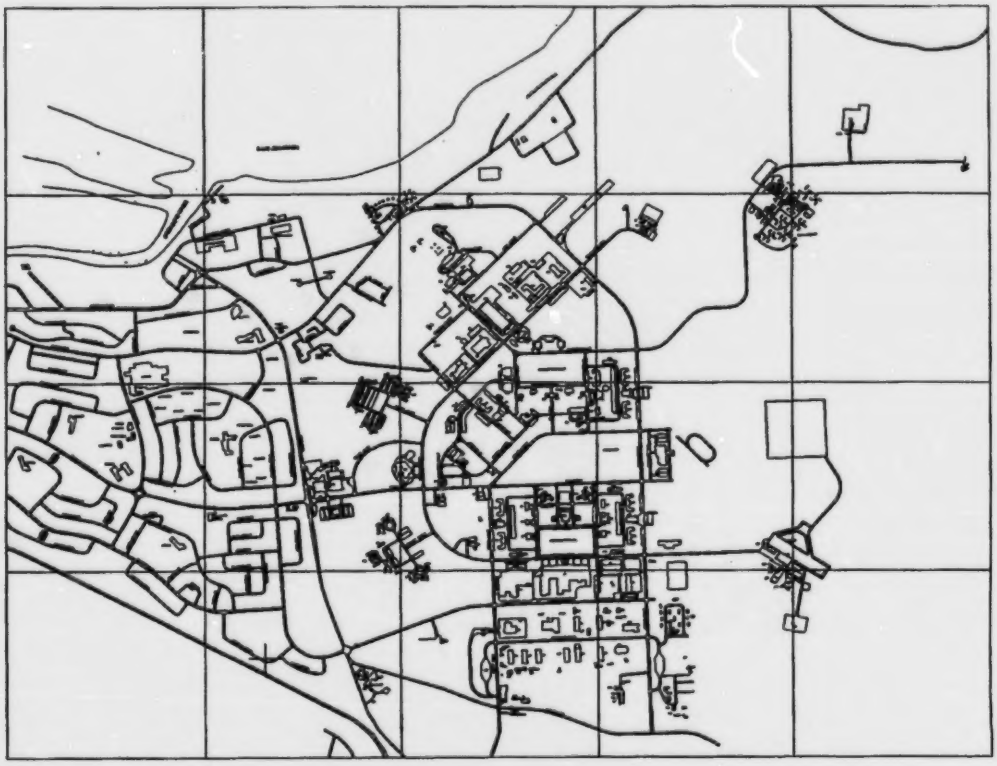


Figure 1. Oromocto and CFB Gagetown Headquarters.

2.2.1 Environmental Ground-Based Measurements

One environmental data collection was used for this study. These data are meteorological and soil moisture data, which were collected from 8 sites on the base and were sampled at least once a day. These measurements are collected for a hydro-geological modelling experiment conducted by the University of New Brunswick and the base meteorologist. These soil moisture data represent a variety of soil types which will make this data base useful for assessing backscatter as a function of soil moisture and possibly soil types. The geographical locations of the meteorological stations and some of the data measurements are located in Appendix A.

The collected data includes parameters such as precipitation, wind velocity, temperature, and soil water potential. These data have been recorded daily, once a day, since July, 1996 and will continue to be recorded for at least one year more. The soil water potential measurements are collected at several depths. For this study, only the shallowest depth at 10 cm, was used since the penetration depth of C-band radar in soil is approximately 5 – 10 cm. The soil water potential indicates how well the soil holds water.

For these measurements, 0 bars indicates a saturated soil while 2 bars indicates a very dry soil.

At each CFB Gagetown meteorology site, the soil water potential measurements are taken from two micro-environments with different soil characteristics. The soil and vegetation characteristics at these sites are documented in [2] and [3]. Examples of the soil moisture data from July, 1996 until October, 1997 at meteorological stations 4 and 7 are shown in Appendix A.1. Also plotted in these figures, is the precipitation. Here the solid lines represent the soil water potential and the dotted lines represent the precipitation levels. It should be noted that these measurements do not produce reasonable results at freezing temperatures and therefore most of the winter measurements should be ignored.

Since the dielectric constant changes by a factor of about 20 from standing water cover to dry soil, the backscatter reflection coefficients for soil are very dependent on moisture content [4]. General descriptions of the soil at meteorology station 4 sites a and b are respectively, a soil that drains moderately well and has natural vegetation cover of grass and moss, and a soil which drains imperfectly and is covered with grass and sedge vegetation. The trafficability at meteorology station 4a is moderate when wet and slightly worse at station 4b [2,.3]. At meteorology station 7 sites a and b the soil descriptions are respectively a soil which drains very poorly and is vegetated with sphagnum, and a soil which drains moderately well and is covered with starflower vegetation. References 2 and 3 indicate that F soil trafficability in wet conditions is very poor at station 7.

2.2.2 Geomatic Data

Geomatic data was provided to us by Geomatics, CFB Gagetown and J2 Geomatics. We have used J2 Geomatics' Grassland software product and their vmap level 2 data product of the base, for referencing environmental information about the base. CFB Gagetown also provided us with more recent environmental geomatic information for the base.

Below is a list of relevant maps which convey information like topography, forestry, geology and other environmental features.

- Map of CFB Gagetown; 1997, series A702, Map MCE 24, TR 93, Edition 14 and 15. Mapping and Charting Establishment, DND, Mgen G. R. Pearkes Building, Ottawa, Ontario, Canada.

- Geological Map of New Brunswick, 1979, Map N. R.-1, 2nd Edition, Department of Natural Resources, New Brunswick, Canada.

3. MULTI-TEMPORAL RADARSAT IMAGERY DATA

Radarsat images of CFB Gagetown, New Brunswick, Canada have been collected by DREO since April 6, 1996. These images were selected so that all seasons were represented, with the intention of capturing the multi-temporal natural environment as recorded in imagery. Radarsat's orbit has an exact repeat cycle of 24 days and most of the fine beam modes (e.g.; Fine 2 or 4, [F2 or F4]) listed in Table 1, were chosen within these limits so that CFB Gagetown was the centre scene. Below in Table 1 is a list of DREO's collection of CFB Gagetown images, as well as pertinent information about these data. Further information about the beam and data type can be found in [1].

Date	Product Type	Beam Type	Truthing [Y/N]	Truthed Target Types	Radarsat ID #, Record #
04/06/96	RAW	Stand -ard	No	None	M0007542, 36
05/09/96	SLC	F4	Yes	Moving M109s, wheeled & tracked vehicles	M0009635, 26
05/16/96	SLC	F2	Yes	Firing Points, vehicles including 5/4 ton trucks	M0009643, 27
08/13/96	SLC	F4	Yes	Targets of opportunity in air photographs	M0068968, 41
09/06/96	SLC	F4	Yes	Targets of opportunity in air photographs	M0076779, 45
12/11/96	SLC	F4	Yes	LSVWs, Howitzer guns, MLVWs	M0095985, 99
05/28/97	SGF	F4	No	None	M0115293, 190
06/04/97	SGF	F2	No	None	M0115910, 191
07/15/97	SLC	F4	No	None	M0119972, 233
08/08/97	SLC	F4	No	None	C0006846, 474
02/16/98	SLC	F4	Yes	Trucks, excavator, M113s	M0154506, 567
03/12/98	SLC	F4	No	None	M0159679, 557

Table 1. Radarsat imagery data of Gagetown, NB with reference to truthing availability. Ground-truthing particulars are in Appendix A and military target acronyms are listed in the ACRONYM list at the end of this report. Data product beam types are documented in [1].

In co-operation with this effort, the CFB Gagetown military personnel provided us with ground truthing of the base for some of the days that an image was procured. Table

1 records whether ground-truthing information was collected for an image. This ground-truthing often captured targets during military exercises and these targets varied from military trucks to Howitzer guns. A list of the truthed targets can also be found in Table 1. Note that the ground-truthing for the two following days, August 13, 1996 and September 6, 1996, consisted of aerial photographs, which can be found in Appendix D. The ground-truthed information is documented in greater detail in Appendix A.2 (arranged by day, in sequential order). Note that a list of acronyms at the end of this document provide a translation for some of the military vehicle names used throughout this text.

4. GROUND-TRUTHING BY DREO OF QUASI-STATIONARY TARGETS : SEPTEMBER 29 - OCTOBER 3, 1997

Ground-truthing was conducted by DREO in an effort to identify and make measurements of the stationary and quasi-stationary targets and micro-environments, which were captured in many of the Radarsat images of CFB Gagetown. The reference to quasi-stationarity implies that a feature of the environment is static for long periods, but may change drastically by an event such as an environmental disaster. Below, is a brief overview of the major areas ground truthed by DREO. Detailed ground-truthed measurements and information for these major stationary and quasi-stationary scenes are reported in Appendix C. Minor areas and details about the environment can be found in the daily logs of Appendix B.

4.1 Ground Truthed Regions and Observations

Below follows a list and brief description of major sites ground truthed by DREO at CFB Gagetown. Appendix C provides this ground truthed information in greater detail.

Site 1; Company Defensive Position (COY DFF POSN) At the time of truthing, this combat training region was near completion. It is situated in a vast valley surrounded by hills. Only the command post region, in an elevated portion of the central valley was accessible to us. Main features which were truthed follow; (1) a large berm, 64 m long and command post bunker, (2) several dug-out concrete bunkers or trenches covered by metal doors, and (3) large gravel parking. Most of the area has been cleared of trees and is either covered by brush or grass. Clumps of trees are in the valley near streambeds and near the observational berm. A treed gully, with a creek at the bottom, is found near the command post.

Site 2; Rockwell Demolition This site is at the top of a hill from which a commanding view of the valley and hills beyond can be seen. Judiciously placed on the hilltop is a large concrete bunker (approx. 3m x 4m x 3m) which is camouflaged with a wedge of packed soil and gravel on three sides. The fourth side has a door. Surrounding the bunker, are bare soil and gravel surfaces. Nearby are some large concrete shapes (largest dimension is about 1.5 m), the dirt road approaching the site, and a few small forest stands amidst the predominantly grubbed areas, found nearby and on most of the hillside.

Site 3; Knowlton Hill At the top of Knowlton Hill is a 53 m high tower (according to a map). This tower, a small building and a metal tank (likely containing fuel) are surrounded by a chain link fence. There is another large tank ($\cong$2m long) situated outside of this fenced area. The region next to this site was clear-cut and grubbed recently (refer to Vegetation in Section 2.1 for definition) except for a small stand of trees near the

tower. Other features include a small, maintained cemetery which is further downhill (about 200 m).

Site 4; Gravel Pit A massive gravel pit which was dug in a side of a hill has distinctive stratified layers. It is accessed directly from a gravel road which stems off of Drummond Road. A road next to the pit goes up the hill to a level area where a large, gravel and asphalt parking lot is located. The region is surrounded by trees of mixed species and sizes up to about 10 m in height.

Site 5; Marshy Region and Black Spruce Stand A marshy region extends from Drummond road, just north of its intersection with the South Boundary Road. Air photographs of this region show a distinctive lush texture from which the extent of the boggy area can be estimated. On the other side of Drummond road is an extensive black spruce stand which was inaccessible.

Site 6; Engineers' Airstrip The airstrip is composed of distinct regions which are of different materials (e.g.; gravel, tarmac and concrete). There are ditches along the side of the airstrip. Some of the phases were under construction at the time of the truthing. Nearby, there are roads, an array of upright poles, transformers and buildings. The region is somewhat flat with grass and shrubs near the airstrip. There are mixed tree stands nearby and forests in the distance.

Site 7; Engineers' Austere Village This town, including the roads and infrastructure, were all designed by members of the on-site engineering school. This village was fenced and inaccessible. The surveying plans have been attached to this report. The site includes about 8 to 10 homes, a large garage, different road surfaces (gravel, concrete) in a moderately hilly environment which is near a creek.

Site 8; Cemetery and Castle Grenade Range A large maintained cemetery is contained within a metal chain link fence with dimensions of about 10 m x 18 m. There are many graves from 1841 to 1991 situated there. It is surrounded by tree clumps and it is directly opposite the road from a grenade range area (also inaccessible) called the Castle. The Castle is barren in many spots because explosives have burned the soil's humus layer.

Site 9; Petersville Supply and Fuel Area The storage area was enclosed with a steel gauge fence. Buildings (some metal or with metal roofs), parked vehicles, a large tent, fuel tanks (>6m long), a transformer and large parking lots were other possible targets outside of the fenced area. Petersville is near the top of a gently sloped hill in a moderately hilly region which is surrounded by forests. This military supply depot includes several large parking lots, buildings and an airstrip. The site that we truthed is at the far edge of this development, next to a large forested region. Transient traffic is likely to occur here and consequently be captured in the Radarsat images.

Site 10; Blissville Airstrip This airstrip has not been maintained for many years and has large craters (1m wide) on the surface where grass and weeds grow. The measured runway length and width is 1.2 km and 45 m respectively. At each end of the runway are aprons, which are pointed in opposite directions. A short adjoining leg, perpendicular to the runway also has an apron. Nearby are small buildings, a small transformer and adjoining

dirt trails or roads. Adjacent to the airstrip is a group of homes and a railway which were not truthed. Railroad positions may be inferred from a geo-referenced air photograph of the region (Appendix D, photo# 97-2508). The region is a fairly flat farming community. Grass and small shrubs surround the airfield with forested regions 200 m away.

Site 11; Red Pine Stands Several natural, large red pine stands were found alongside Highway 660 and CFB Gagetown's gate 68. Some of these were Commercially Thinned (CT). Also, a mixed forest with extremely large red pines (25 m high) was found near gate 68.

Site 12; Forest Fire Airplanes at Fredericton Airport It was confirmed that most of these World War II airplanes on the tarmac at the airport have not been moved for at least a year. The planes are near some aluminum buildings, gas tanks and other airplanes at the edge of the airport. The airport is directly off of Highway 1 and near Fredericton and the St. John River. The region is flat with either grass or scrub brush growing there.

Site 13; Military Vehicles on Display at CFB Gagetown's Entrance Some examples of military vehicles are displayed at the entrance to the base on concrete forms in Oromocto, New Brunswick. A Sherman tank, Bren Gun Carrier and Howitzer (M114) were ground truthed. The immediate area is well maintained with nearby manicured trees and plush grass. Behind these displayed vehicles is a parking lot.

Site 14; Sand and Gravel Pit Near the North-East Corner of the Base Three excavation sites in close proximity to each other were found with varying grades of sand and gravel. All these pits are attached with a gravel road. The largest pit is a short distance (50 m) from Highway 102. This area is at the northern edge of a fire-scarred forest, which was damaged in 1986. The forest has now regenerated and there is now a mixed forest interspersed with large burnt tree remnants. Near the highway, there are some large pines and a house. There may be some vehicles (e.g.; graders) in the pit regions when the satellite images were captured.

Site 15; December 11, 1996 Site (Ground-truthed by the Base) We supplemented the December 11, 1996 ground truth information (near the Lawfield Bivouac site) which was supplied to us by the personnel from CFB Gagetown. Further information about the background terrain and the configuration of the Howitzer guns was obtained. A wrecked and burnt vehicle which was in 3 major pieces was also ground truthed. This region is on a hillside and the vegetation cover varies from bare soil at the top of the hill to grass and treed areas along the slopes.

Site 16; Transformer at Oromocto A very large transformer within a metal gauge fence was truthed. Only the transformer position and the fence dimensions were obtained. The immediate region was in a gentle gully covered with grass and scrub brush. Nearby, were Oromocto housing developments and MacDonald Road.

5. PRELIMINARY DATA ANALYSIS

Preliminary data analysis is included in this report with an emphasis on backscatter estimates for different environmental conditions. In this section, a brief documentation of the analysis completed in this report is followed by the analysed results.

5.1. Data Analysis

Backscatter (σ°) and Target-to-Clutter Ratio (TCR) results are provided here and are compared to other values in the literature.

The Radar Cross Section (RCS) per unit area, σ°, otherwise known as the backscattering coefficient, provides an estimate of the antenna's received backscattered power relative to the transmitted power, as a function of angle, and is defined as,

$$\sigma^\circ(\theta) = P_r(\theta)/K \qquad (1)$$

Here, θ, P_r and K are respectively, the look angle, the received power and a constant which is dependent on system parameters like transmitted power and frequency. For focused SAR data, K is

$$K = \frac{P\lambda^2 G^2(\theta) l c \tau}{4(4\pi)^3 R^4 \sin\theta} \qquad (2)$$

where P is the transmitted power, λ is the wavelength, G is the antenna gain pattern , θ is the incidence angle defined as the angle from the vertical normal to the Earth's surface, l is the along track length of the antenna, τ is the time pulse width and R is the distance between the antenna and the beam cell. It should be noted that the backscattering coefficient can have different polarization possibilities. These are not defined here, since the Radarsat imagery, which is analyzed in this report, has only horizontal transmit and receive polarizations.

The TCR is a ratio of the target backscattering coefficient to the clutter backscattering coefficient. Many of the targets here, represent between a fraction of a pixel and two pixels on the image. Consequently, it is often ambiguous whether the target is detected on the image, particularly when the magnitude of the environmental clutter is similar to the target clutter. Also, without extremely accurate geo-referencing it is impossible to determine what proportion of the target backscatter is within a pixel. In addition, the number of samples for each target type is small. Therefore these TCR estimates are not statistically significant and for all of these reasons above, a very simple estimate for TCR was made. Either the mean or maximum backscatter value was used for the TCR estimates in this report, depending on what was suitable. The simple expression used for TCR estimates is as follows,

$$TCR_{\xi} \cong \frac{\sigma_T}{A\sigma_C} \qquad (3)$$

where A, σ_T and σ_C represent, respectively, the fractional area of the target in the σ_T estimate, the backscattering coefficient for the target, the backscattering coefficient for the background clutter and ξ represents either the maximum or mean value of σ_T was used for the calculation. This equation assumes that the target backscatter is much greater than the background backscatter. All the TCR estimates in this report are in regions where the background backscatter is small relative to the target.

5.2. Clutter Results

The analysis presented here, compares target and environmental clutter from two extreme seasonal conditions; spring with no foliage (other than fir trees) and summer with fully foliated vegetation. Since a temporal comparison is made, only the stationary areas which were ground-truthed by DREO and which are documented in this report, are used. The categories include: airstrips and a group of airplanes on one of these airstrips, marshlands, grasslands, pine forests, cylindrical gas tanks and gravel parking lots. The results from each of these categories is listed in separate tables and compared to other values found in the literature. Note that the backscattering coefficient mean, maximum (max), minimum (min), standard deviation and median are presented here for N, the number of image sample values (with dB values in brackets for all statistics except variance). These statistics are based on the backscattering coefficient and not its logarithmic or dB value. Also, both images used for this analysis are Radarsat Single Look Complex (SLC), Fine, Type 4 (F4) images. Therefore the incidence angle is between 43 to 46 degrees. Since this is a preliminary study, samples from the same area are compared for the two dates, but are not necessarily the exact geographical place. These backscattering coefficient results presented here are representative of different clutter types from two days which differ in season. A more rigorous study with more attention to the geographic position will be presented in the future

Other targets and clutter had been considered, but it was difficult to determine where the targets were in the image(s) without more precise geo-referencing. These targets were particularly difficult to find if the surrounding terrain was mountainous and/or the approaching roads were track roads (particularly when the surrounding region was a grubbed area). Most of the difficulties are associated with the resolution of the Radarsat image, since most land targets are often not as large as one pixel. In Section 5.3, there is a brief discussion about the error sources associated with backscatter estimates from Radarsat images.

In the developed areas there were many ambiguities which were likely due to human related transient effects. This was particularly a problem, since it was impossible for us to have the base truthed for all locations. For instance, the backscatter results for the fuel tanks at Camp Petersville and the fire planes at Fredericton Airport may not be correct, because they are in places where potential transient targets may park nearby. These

transient targets could be confused or smeared with the target of interest. Even if geographic location errors were reduced to 10 m, the cumulative error with the GPS error measurement (typically 10 - 15 m) represents a total error which is much larger than the distance(s) between these transient targets and the measured target(s). Therefore, without adequate ground-truthing many of the smaller targets' backscatter estimates may not represent seasonal variation at all, but rather traffic variations on the base.

In order to emphasize backscatter variability, we have compared two days with completely different environmental conditions. One day is in summer and is sunny, clear and dry (August 8, 1997). The other image was procured on a cold spring day (March 12, 1998, -12°C), which was a day after a large rainfall that resulted in flooding at some locations. There was snow in many locations with variable depths (0 - 20 cm) and ice was found in some locations also.

5.2.1 Airstrips and Airplanes

Below are two tables that provide backscatter estimates for three airstrips; Blissville (referred to as Blissvil in Table 3; it is an old and unmaintained airstrip), Airstrip 1 (referred to as Air 1 in Table 3; it is a newer airstrip with regions of different surface types, such as concrete and tarmac) and Fredericton Airport (referred to as Fred air in Table 3; it is a conventional municipal airstrip). Tables 2 and 3 represent the results for respectively, the summer and spring days. A 'flatness' discriminator, which is documented in [5], was used for selecting the airstrip samples. From visual inspection, this discriminator appeared to select the samples quite well.

In Table 2, it was not possible to distinguish the Blissville airstrip from the background clutter and consequently no values are given. However, this same airstrip was visible in the Radarsat spring image, as observed in the Table 3 results. A discussion with Range Control at the base revealed that the fire brigade was camping at the Blissville airstrip during the summer time, and most likely at the same time that the summer image was captured. This may provide an explanation for why the airstrip was not visible in the summer image. The ambient backscatter of the Blissville airport region at the time of the satellite pass over for the August 8, 1997 image had a mean σ° of -20.5 dB.

The results in Tables 2 and 3 indicate that the backscatter from the airstrips are similar to each other for a particular season, but substantially dissimilar between seasons (about 5 dB). It is speculated that the larger estimates in the spring may be due to double-bounce backscattering mechanisms from packed snow placed along the edges of the runways. It is likely that only Blissville would be entirely snow covered in the spring, which explains the smaller backscatter returns despite the poor (and rough) surface at Blissville.

The backscatter from the fire planes (see site 12, Appendix C) at Fredericton Airport was also estimated. These planes were lined up very close to each other, which resulted in a blurred imagette from the ensemble rather than distinct backscatter returns from each plane. Individually, these planes are about the same size as one resolution cell of the image. Hence, for most situations, it is impossible to ascertain whether the backscatter is really from these known targets without extremely accurate geo-referencing. Also,

identifying the target is more complicated since the target's backscatter is often split between different resolution cells. Consequently, the target's backscatter is averaged with the surrounding environmental clutter, which can be near the magnitude of the target's backscatter. For all these reasons, it is very difficult to identify most land targets (with the exception of large targets such as large planes) in most Radarsat imagery. For these estimates the most likely backscatter imagette was chosen.

Airstrip	σ° for August 8, 1997 (dB in brackets)					
	Mean	Max	Min	Median	Standard Deviation	N
Blissvil	N/A	N/A	N/A	N/A	N/A	N/A
Air 1	1.87×10^{-3} [-27.3]	5.46×10^{-3} [-22.6]	1.33×10^{-5} [-48.8]	1.76×10^{-3} [-27.6]	1.39×10^{-3}	117
Fred air	2.67×10^{-3} [-25.7]	9.12×10^{-3} [-20.4]	1.20×10^{-5} [-59.2]	2.15×10^{-3} [-26.7]	2.12×10^{-3}	1314

Table 2. Summer backscatter statistics for airstrips at CFB Gagetown. Here, N refers to the number of samples. (Note: N/A denotes not applicable. See text above.)

Airstrip	σ° for March 12, 1998 (dB in brackets)					
	Mean	Max	Min	Median	Standard Deviation	N
Blissvil	5.89×10^{-3} [-22.3]	2.22×10^{-2} [-16.5]	6.04×10^{-6} [-52.2]	4.24×10^{-3} [-23.7]	5.22×10^{-3}	1795
Air 1	1.54×10^{-2} [-18.1]	1.39×10^{-1} [-8.6]	5.45×10^{-5} [-42.6]	6.88×10^{-3} [-21.6]	2.41×10^{-2}	227
Fred air	9.79×10^{-3} [-20.1]	4.84×10^{-1} [-3.2]	1.32×10^{-6} [-58.8]	4.94×10^{-3} [-23.1]	1.83×10^{-2}	5445

Table 3. Spring time backscatter coefficient statistics for airstrips at CFB Gagetown. Here, N refers to the number of samples.

The following backscatter results in Table 4 are crude estimates using the aforementioned blurred imagette. There were several permanent and transient targets (e.g.; fuel tanks and parked vehicles nearby) in close proximity to each other and it is possible that the results in Table 4 may not represent these planes.

If these results are representative backscatter values for these planes, then it should be noted that the backscatter in the spring is very large relative to the summer. However, since N, the number of image datum used in the summer statistics is about double the number used in the spring, these results may indicate that the backscatter from the planes is distributed over more pixels and hence represents a smaller portion of the planes' backscatter in each pixel. For instance, if the backscatter contribution from one plane, which is assumed to have a cross-sectional area of one pixel, is distributed evenly over three image pixels, then, one would expect one third of the planes's backscatter contribution in each of these three pixels relative to situations where the entire backscatter contribution from the plane is mostly in one pixel.

The fire plane backscatter results do not have sufficient samples to be statistically significant. Nevertheless, TCR estimates were calculated from this limited sample set. The target backscatter is likely from 6 planes, which have an approximate cross sectional area of about 1 pixel size apiece. The summer (spring) TCR results range from about 25.7 (20.8) dB for the maximum fire plane backscatter, to about 24.6 (20.4) dB for the mean fire plane backscatter. The seasonal difference between these TCR estimates is about 5 dB different in summer than in spring. This may be due to corner reflections in the spring image from either pools of water or wet snow next to the airplanes since a heavy rainfall had occurred the previous day.

Date	σ^o of Fire Planes at Fredericton Airport (dB in brackets)				
	Mean	Max	Min	Standard Deviation	N
August 8/97	2.08×10^{-1} [-6.809]	9.49×10^{-1} [-0.226]	9.20×10^{-3} [-20.036]	2.49×10^{-1}	20
March 12/98	1.50×10^{0} [1.760]	2.68×10^{0} [4.273]	5.21×10^{-2} [-1.283]	1.20×10^{0}	12

Table 4. Backscatter coefficient estimates from fire planes at the Fredericton Airport. Here, N refers to the number of samples.

5.2.2 Marshland

There were several regions which were quite marshy near some of the rivers and creeks in the Gagetown region. Below in Tables 5 and 6 are examples of marshland

backscatter estimates for the two aforementioned dates. These estimates are from two sub areas of the bog (see Site 5, Appendix C) and the marshland within the southern part of Gagetown Island (referred to as S Gage in Tables 5 and 6) where Ducks Unlimited has cut wavy channels through the marshland.

Pope et al [6] studied multi-temporal backscatter results over the Yucatan Peninsula, Mexico and found large backscatter increases when flooding conditions were prevalent. The mean values in Tables 5 and 6 are smaller than those found in [6] which is likely due to different vegetation and water levels. However, the results are similar to [6] with respect to the large increases of backscatter (+6 dB) for the summer S Gage image, where the Ducks Unlimited water passageways are similar to a flooded condition. The backscatter for bog 1 (summer) is also comparable to S Gage, which may indicate flooding or water cover occurring there also. This is further supported by the fact that when this site was ground truthed by DREO there was a creek flowing near where bog 1 is located.

The spring backscatter from the S Gage marshland is considerably smaller than the summer image. This may be because very little multi-path mechanisms occur since the vegetation is likely frozen and there is snow and ice cover (Ducks Unlimited indicated that at the time of the flood, the islands were snow and ice covered). In contrast, the spring bog estimates are about the same magnitude and almost as large as the summer bog 1 estimate. This may possibly be explained by the fact that there may have been flood like conditions due to the large precipitation values a few days prior to the procurement of the spring image. This would result in swollen rivers and streams flowing, despite freezing temperatures. Since the bogs' surfaces are rough, this may result in larger backscatter values from the interaction of these rough surfaces with the water.

Marsh	σ° for August 8, 1997 (dB in brackets)					
	Mean	Max	Min	Median	Standard Deviation	N
Bog 1	1.05×10^{-1} [-9.779]	6.80×10^{-1} [-1.673]	5.55×10^{-4} [-32.557]	6.89×10^{-2} [-11.618]	1.16×10^{-1}	350
Bog 2	2.84×10^{-2} [-15.467]	2.87×10^{-1} [-5.408]	2.98×10^{-4} [-35.256]	1.94×10^{-2} [-17.113]	3.29×10^{-2}	176
S Gage	1.32×10^{-1} [-8.796]	1.38×10^{0} [1.405]	2.13×10^{-7} [-66.737]	7.40×10^{-2} [-11.308]	1.58×10^{-1}	10000

Table 5. Backscatter estimates for marshland on August 8, 1997. Here, N refers to the number of samples.

The backscatter from marshland is very complicated. When open water is prevalent within the marshland vegetation, the mechanism for corner reflection scattering can occur. This is observed in the large maximum backscatter estimates found in Tables 5 and 6 which are comparable to the backscatter from targets (like fire planes and other large metallic objects). Ducks Unlimited (personal conversations with DREO) indicated that it was very difficult to get into any of these regions and very unlikely that any man-made vehicles were there.

Marsh	σ° for March 12, 1998 (dB in brackets)					
	Mean	Max	Min	Median	Standard Deviation	N
Bog 1	9.45×10^{-2} [-10.247]	1.45×10^{0} [1.612]	5.38×10^{-5} [-42.692]	6.06×10^{-2} [-12.174]	1.17×10^{-1}	806
Bog 2	9.66×10^{-2} [-10.152]	4.01×10^{-1} [-3.971]	2.49×10^{-4} [-36.038]	7.13×10^{-2} [-11.469]	8.72×10^{-2}	272
S Gage	3.85×10^{-2} [-14.141]	3.59×10^{-1} [-4.447]	1.85×10^{-5} [-47.331]	2.44×10^{-2} [-16.120]	4.34×10^{-2}	1681

Table 6. Backscatter estimates for marshland on March 12, 1998. Here, N refers to the number of samples.

5.2.3 Grassland

The Enniskillen region (CFB Gagetown, Area 57) was used as a grassland location for this analysis. This area was grubbed about 20 years ago and is now almost entirely grass covered. For each of the two images, three fairly homogeneous areas (Ennis 1a-3a in Aug/97 and Ennis 1b-3b in Mar/98) are used to determine backscatter estimates for grass covered regions and these statistics are displayed in Tables 7 and 8. These selected areas from the two different days came from more or less the same regions except they were chosen for homogeneity. For instance, in the spring the rivers and streams were wider and possibly flooded some of the grasslands there. These uncertain regions were not selected for analysis in order to reduce parameter considerations.

These results indicate that most of the mean backscatter values, σ°, are about -14.0 dB, which is near the same value (within 0.5 dB) found by [7]. There is substantial variation in the summer image (as much as 7 dB) as demonstrated by the comparison of Ennis 2a with Ennis 1a and 3a. It is speculated that this variability is most likely due to local moisture variation (drainage characteristics), roughness and perhaps vegetation variability. This is further supported by other results in the literature [4, 8-11]. Unfortunately, this

region was not accessible for ground truthing, with the exception of aerial photographs. Most air photographs show grass cover and negligible shrub or tree cover which indicates that moisture variability and surface roughness are likely the contributing factors to the large backscatter variability within the region during the summer.

Grass	σ° for August 8, 1997 (dB in brackets)					
	Mean	Max	Min	Median	Standard Deviation	N
Ennis 1a	3.95×10^{-2} [-14.029]	2.53×10^{-1} [-5.976]	6.06×10^{-5} [-42.177]	2.84×10^{-2} [-15.455]	3.79×10^{-2}	484
Ennis 2a	5.15×10^{-3} [-22.880]	3.22×10^{-2} [-14.921]	2.59×10^{-5} [-45.866]	3.59×10^{-3} [-24.449]	5.27×10^{-3}	253
Ennis 3a	3.02×10^{-2} [-15.200]	1.77×10^{-1} [-7.524]	5.57×10^{-5} [-42.544]	1.97×10^{-2} [-17.049]	3.16×10^{-2}	189

Table 7. Backscatter estimates for the grassland regions in the Enniskillen area on August 8, 1997. Here, N refers to the number of samples.

Grass	σ° for March 12, 1998 (dB in brackets)					
	Mean	Max	Min	Median	Standard Deviation	N
Ennis 1b	4.29×10^{-2} [-13.672]	2.59×10^{-1} [-5.870]	9.00×10^{-5} [-40.458]	2.91×10^{-2} [-15.346]	4.39×10^{-2}	204
Ennis 2b	2.86×10^{-2} [-15.439]	1.38×10^{-1} [-8.617]	8.57×10^{-5} [-40.671]	2.20×10^{-2} [-16.576]	2.63×10^{-2}	195
Ennis 3b	4.27×10^{-2} [-13.700]	2.70×10^{-1} [-5.683]	9.04×10^{-5} [-40.438]	2.76×10^{-2} [-15.599]	4.40×10^{-2}	255

Table 8. Backscatter estimates for the grassland regions in the Enniskillen area on March 12, 1998. Here, N refers to the number of samples.

All of the spring images are very similar which is likely due to the fact that the ground was still mostly frozen and snow covered when the satellite passed over. The snow cover may have been wet at the time, but this moisture would likely be more or less the same everywhere, except near open water. Ennis 2b is about 1.5 dB different relative to Ennis 1b and 3b, which may be due to moisture variability.

5.2.4 Red Pine Forest

The location of one of the red pine forests (in Site 11) was estimated from its position along the highway. Table 9 shows backscatter estimates from the same red pine forest for the two dates. From these two image samples, the mean σ° does not vary much throughout the year (0.6 dB). However, the maximum estimates do vary by 2.5 dB and may be related to environmental conditions from either wet snow in the spring or from the underbrush foliation in the summer.

These preliminary estimates are very near the jack pine estimates of (-6.5 dB) found by [12] for a large variation of incidence angles. Since the jackpine's structure is similar to a red pine in terms of the parts (e.g.; the trunk, branches and needles), but different with respect to the orientation and sizes of these parts, it is expected that the scattering would be somewhat similar, but not the same. Reference 13 found very similar σ° values for an old pine forest (-8.0 dB at incidence angle of 26°) to those presented in Table 9 with an incidence angle of about 45°.

Date	σ° for pine forest [site 11] (dB in brackets)					
	Mean	Max	Min	Median	Standard Deviation	N
Aug 8/97	1.58×10^{-1} [-8.016]	1.09×10^{0} [0.358]	3.99×10^{-4} [-33.990]	1.01×10^{-1} [-9.949]	1.66×10^{-1}	121
Mar 12/98	1.84×10^{-1} [-7.361]	6.10×10^{-1} [-2.149]	2.54×10^{-3} [-25.947]	1.29×10^{-1} [-8.910]	1.64×10^{-1}	66

Table 9. Backscatter estimates for a pine forest on August 8, 1997 and March 12, 1998. Here, N refers to the number of samples.

5.2.5 Gas Tanks at Camp Petersville

The two gas tanks at site 8, Camp Petersville, were used as an example of a long target (>6m length) with a cylindrical shape. Since spherical shapes and corner reflectors have similar backscattering characteristics, it is expected that these metallic, cylindrical tanks

with rounded, semi-spherical ends, would provide large backscatter results for certain conditions. Since only two estimates, the maximum and minimum, were obtained for the two tanks, no statistics are provided here. It should be mentioned that for the March 12, 1998 image, there were several bright areas and it was impossible to distinguish the backscatter of these tanks from other possible sources. Therefore in Table 10, the March 12, 1998 result may be incorrect. The most likely area was used for this estimate, but, the image indicated the possibility of transient targets near these tanks. As aforementioned, without sufficient ground truthing, and very accurate geo-referencing, it is impossible to distinguish environmental variability from cultural variability.

Date	σ^o for gas tanks at Camp Petersville (dB in brackets)					
	Mean	Max	Min	Median	Standard Deviation	N
Aug 8/97		1.47×10^{0} [1.680]	1.33×10^{0} [1.230]			2
Mar 12/98	*see text above	5.39×10^{-1} [-0.2683]	3.39×10^{-1} [-0.4697]			2

Table 10. Backscatter estimates of the long gas tanks at Camp Petersville, for August 8, 1997 and March 12, 1998. Here, N refers to the number of samples.

5.2.6 Gravel Parking Lot

The backscatter characteristics for the large gravel parking lot at site 8, Camp Petersville, is compared for the 2 days and these results are reported in Table 11. The mean backscattering coefficient estimates, as expected for relatively flat surfaces, are small (about –18.5 dB) relative to other types of environmental clutter. Little variability between the estimates for the two days is evident. Likely explanations for this lack of variation is that either 1) the snow in the spring image was dry and transparent or 2) most of the snow in the spring image had been removed from the parking lot. Since the general area contained refueling tanks, the latter explanation is more probable.

Date	σ^o for gravel parking lot at Camp Petersville (dB in brackets)					
	Mean	Max	Min	Median	Standard Deviation	N
Aug 8/97	1.33×10^{-2} [-18.776]	5.28×10^{-2} [-12.776]	2.84×10^{-4} [-35.473]	1.03×10^{-2} [-19.996]	1.28×10^{-2}	72
Mar 12/98	1.41×10^{-2} [-18.508]	6.98×10^{-2} [-11.560]	2.83×10^{-4} [-35.482]	1.09×10^{-2} [-19.610]	1.21×10^{-2}	80

Table 11. Backscatter estimates of the parking lot at Camp Petersville for August 8, 1997 and March 12, 1998. Here, N refers to the number of samples.

5.3. Error Sources of Radarsat Backscatter Estimates

One of the most difficult tasks in this study has been to correctly identify a target within the imagery without accurate geo-referencing. This difficulty is even more severe for targets with dimensions of the same order as the image's resolution cell. Geographical information supplied by Radarsat can be inaccurate because these values do not account for an earth surface which departs from sea level. Additionally, Radarsat's exact position is not always known precisely. The resultant geographical error can be as great as 2 km away in range. Typically, for moderate terrain variability, the positional errors are the order of 200 m. Since most land targets are less than one Radarsat resolution cell it is very difficult to locate targets in the image and this difficulty is compounded with geographical uncertainties of 200 m or greater. Sometimes if the target is near infrastructures, which are well defined within the imagery, the target can be detected. However, if the target is located in a region which is not well developed (as is the case for most CFB Gagetown battle exercise sites), it is virtually impossible to find the target. Additionally, for many natural environments, corner reflection backscattering mechanisms are common and can result in large backscatter values which make it more difficult to distinguish targets from the clutter.

For this study and for most typical scenarios, the targets on land are small relative to one Radarsat resolution cell. As aforementioned, this in combination with geographic uncertainty has made identifying targets particularly difficult. Another problem is that the image cells are often inadequate sample sizes for determining a land target's backscatter. The backscattered energy from most targets is often distributed amongst adjoining pixels. It is impossible to determine this distribution amongst the pixels and consequently the backscatter for an individual target, particularly since the background clutter will also affect the backscatter value. This is even further complicated by the fact that the backscatter from a target also depends on the orientation of the target relative to the boresight angle. Consequently, backscatter estimates for most land targets with low resolution imagery are difficult measurement to make. Statistical estimates from a sufficient number of targets and

knowledge of the orientation is one way of achieving a reasonable result. In order to determine the target's backscatter adequately, the knowledge of the statistical variability of the background clutter type is required. For this study, it was very difficult to find most of the ground truthed targets in the imagery, since most of the targets were smaller than a Radarsat cell and were in regions where it was difficult to distinguish them from the environmental clutter. This target identification problem indicates that in order to determine backscatter estimates for targets adequately, a more refined and staged experiment is required in a region with low backscatter and with many targets orientated at many directions.

Another problem with the analysis of the quasi-stationary targets is that there are transient targets which can appear at any time near these targets of interest. These transient targets confuse the interpretation since they either cannot be distinguished from a target of interest or it is difficult to assess which is the target of interest. These identification problems are compounded by the inaccuracies associated with geographic referencing.

All of the images, which were analyzed here, were Single Look Complex products. This data product is susceptible to speckle noise, which makes it more difficult to find targets in the imagery, particularly when they are small. However, applying a speckle filter (Lee filter) to the images did not improve the capability of identifying these targets. It is speculated that this is because many natural features have large backscatter values that are comparable to small land targets. For instance, corner reflection scattering mechanisms from a small tree clump provides large backscatter values. This scattering mechanism in combination with wet regions, such as bogs, can often result in large backscatter increases, that are typically about 6 dB [6]. It is possible that the large background backscatter values often found in the Gagetown imagery, may be associated with the fact that a large proportion of Gagetown is boggy, with very rough surfaces (gross features have typical mean roughness lengths and heights of 70 and 25 cm respectively; fine texture clumps or vegetation have a variety of lengths depending on the environment) and with a variety of vegetation types.

The fact that most small land targets are difficult to identify from Radarsat's imagery, indicates Radarsat's limitations as a surveillance method. Possibly, with additional information, this imagery could be used for the surveillance of small targets. In addition to smaller image resolution cell sizes, detection capability could be improved either from polarimetric data or from data fusion with other imagery.

Below, is a list of some of the quasi-stationary targets, which were difficult to locate with Radarsat. This list is given here, mainly to indicate the limitations of Radarsat with only one channel (HH), with large resolution cell sizes relative to small land targets and without sufficient geo-referencing capability.

- The bunkers and berm at the Company Defensive Operation (site 1) were difficult to find because of the background speckle from the rough, grubbed hillside and because these bunkers are smaller than the resolution cell of the sensor. With better geo-referencing, it may be possible to find these. The berm was not positively distinguished on the image, although a linear feature was noticed in the area.

- For many of the towers, (e.g.; Knowlton [illegible]) which are of metallic composition, it was expected that either linear shadow(s) or corner reflection(s) signatures might indicate their location. However without accurate geo-referencing, these were also difficult to find. Additionally, these towers were not near infrastructures, which were easily distinguishable on the image. For instance all the approaching roads had very rough surfaces which are not easily discernible on a Radarsat image, particularly if the surrounding environment (e.g.; grubbed) is similar. Most of these towers were commonly in areas where there was large speckle levels in the imagery. In contrast, at Airstrip 1 (site 6), the array of wooden poles was (most likely) visually detectable in the imagery. These poles are probably more detectable because the surface at the airfield is relatively smooth compared to most target locations documented here.

- The targets on display at the base headquarters (site 13) in Oromocto could not be found. This was likely due to the congestion in the urban environment, the resolution of the image cell, the target density in the area and many corner reflection mechanisms in the area.

- The destroyed vehicle at site 15 was not discernable in the imagery. This wreck was surrounded by many tree and shrub clumps. Both the tree clumps and the wreck have similar backscatter mechanism properties. For the Radarsat resolution cell sizes, it is very difficult to distinguish these natural corner reflection scattering mechanisms from man-made corners. Additionally, the terrain surfaces were extremely rough here which provides greater speckle noise.

Radarsat imagery, however, is very useful for determining environmental backscatter information, particularly for environmental features which extend over large areas and are represented by a statistically significant number of samples. However, for environmental features, which were more locally confined and/or smaller in area, it was difficult to identify the location and limits of these features without very accurate geo-referencing capabilities.

6. DISCUSSION AND CONCLUSION

The purpose of this report is to document the ground-truthing for a multi-temporal collection of Radarsat images of CFB Gagetown, NB. Additionally, this report provides preliminary backscatter and Target to Clutter (TCR) statistical results for environmental and target clutter. Two fine beam images (with incidence angles between 43 and 46°) were selected for the analysis so that extreme seasonal effects are represented in these results; one image was captured at the end of winter while the other image was procured in the height of summer. Imagery from relatively flat areas were preferentially analysed to avoid confusion regarding incidence angle.

Here the environmental clutter analysis included; marshes, grassland regions and pine forests. Some relatively flat infrastructures were also analysed. These included airstrips' tarmac surfaces and gravel parking lots. Two targets were analysed; a collection of fireplanes at the Fredericton airport and large gas tanks.

Below follows a brief overview of the backscatter results found in the previous section.

In general, most of the environmental clutter results found here correspond well with other values in the literature. Typical environmental clutter backscatter coefficient estimates in summer for grassland, marshland, pine stands were respectively –15 dB, -10 dB and –8 dB. The seasonal backscatter was quite variable between seasons for some environments and conditions. One characteristic, is the fact that environmental clutter can have significant spatial variability, which is often related to either moisture levels or standing water. For instance in marshland regions, standing water variability represented a difference of 6 dB in the backscatter coefficient estimates. CFB Gagetown has many vegetated wetland areas. It is in these regions where very large backscatter returns occur from natural conditions, and these values could be confused with targets.

The airstrips all had about the same backscatter coefficient estimates (e.g.; in summer, about –25 dB), except for when snow or icy conditions prevailed. The gravel parking areas had very consistent backscatter (about –18 dB) throughout the year, possibly because the snow cover was likely removed from these areas in the winter.

It was extremely difficult to detect and consequently analyse most of the truthed targets. This was partly because the targets are small relative to the image resolution cell and partly because the background backscatter was fairly large for most of the scenarios. For this analysis, accurate geographical locations are required since many of the ground truthed targets are not near obvious infrastructures in the imagery. For this analysis the TCR of the aircraft to the airstrip is about 25 (20) dB in summer (spring). From this TCR estimate, and the other environmental backscatter estimates, one may extrapolate that the land targets are easily distinguished from the environmental clutter. This is not the case,

predominantly, because of the variability (as seen in the variance estimates) of some environmental clutter types.

This preliminary study indicates the requirement for determining accurate image geographical locations to help alleviate the identification of target(s) for backscatter estimates. Moderate co-ordinate errors can be about 200 m and GPS location errors for targets are about 10 m. The identification of targets or clutter with these cumulative geographical errors can be impossible, particularly if the background clutter is large or if other transient targets appear in an image. CFB Gagetown has many rough surfaces (e.g.; the vast grubbed, deforested regions) with minimal reference points (e.g.; roads, of which many have rough surfaces) which results in very few identifiable locations in an image. Consequently it is very difficult to identify truthed targets or clutter in the imagery for the remote areas of this base (see 5.3) and for the areas where transient traffic is frequent. This difficulty indicates the inherent limitation of Radarsat imagery for the surveillance of most land targets. For reliable target backscatter estimates, it is advised that targets be located in areas with low backscatter.

It is interesting to note that with only one channel (HH), the capability to classify clutter from the imagery is limited even more. Polarimetric data or data fusion with other imagery would provide more information and an improved probability of target (or clutter) detection.

APPENDIX A. CFB GAGETOWN GROUND TRUTHING AND DATA

In the following appendix, information provided by the personnel at CFB Gagetown is documented. This includes two parts; environment and ground truthing information. The appendix begins with information about two of the base's meteorological stations. Additionally some of the meteorological data is also recorded here. After this, any ground-truthed information collected at CFB Gagetown the day when a satellite image was captured are documented. This ground truthed information is collated in historical order.

A.1 METEOROLOGICAL STATIONS AT CFB GAGETOWN

Data from two meteorological sites on the base were provided to us. From each site, soil moisture measurements were collected from two different types of micro-climates (site a and b). Below is the location of these sites and their soil moisture probes. Following these locations are Figures 2 to 13, which represent the recorded precipitation and soil moisture data for these two stations. Note that a soil moisture of 0 represents a saturated condition while a soil moisture of 2 represents an extremely dry soil which will not be able to sustain most vegetation for any length of time.

It should be noted that the meteorological station 4 was visited during the DREO ground truthing visit. A description of this station is found in the DREO logs for October 3, 1997 (in Appendix B). Photographs can be found in Appendix D.

Below are the locations of the two stations;

- Station 4:

  meteorological station - 45° 44′ 23″ N, 66° 13′ 13″ W

  site a (104 m east of meteorology station) - 45° 44′ 23″ N, 66° 13′ 07″ W

  site b (109 m southwest of meteorology station) - 45° 44′ 20″ N, 66° 13′ 16″ W

- Station 7:

  meteorological station - 45° 39′ 09″ N, 66° 32′ 17″ W

  site a (126 m northwest of meteorology station) - 45° 39′ 09″ N, 66° 32′ 23″ W

  site b (76 m northeast of meteorology station) - 45° 39′ 12″ N, 66° 32′ 14″ W

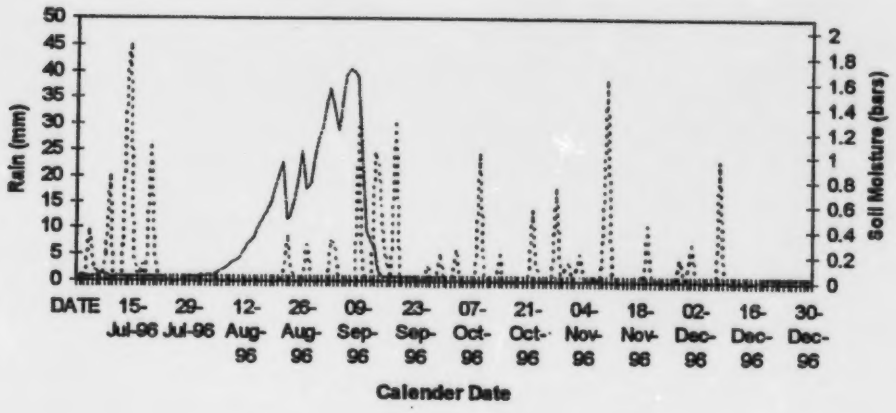


Figure 2. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 7 (location a) are shown as solid and dashed lines respectively (July 15 /96 – December 30/96).

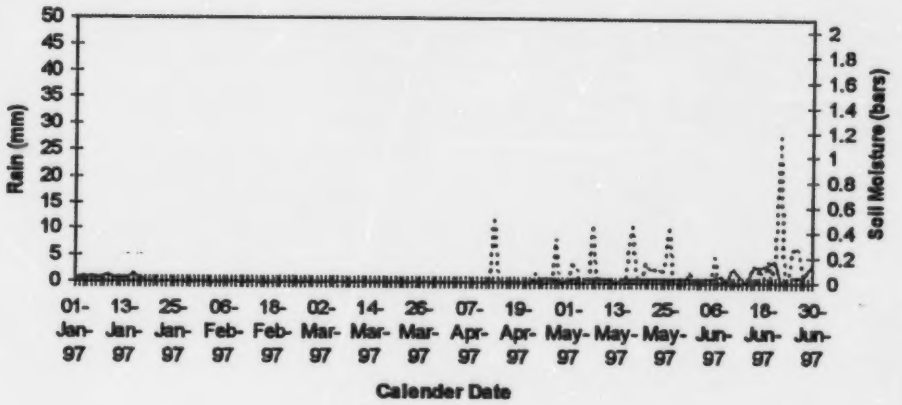


Figure 3. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 7 (location a) are shown as solid and dashed lines respectively (January 1/97 – June 30/97).

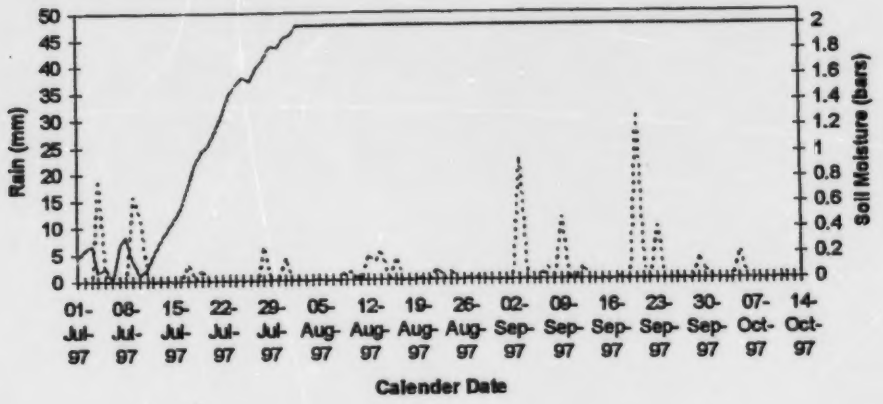


Figure 4. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 7 (location a) are shown as solid and dashed lines respectively (July 1/97 – Oct 14/97).

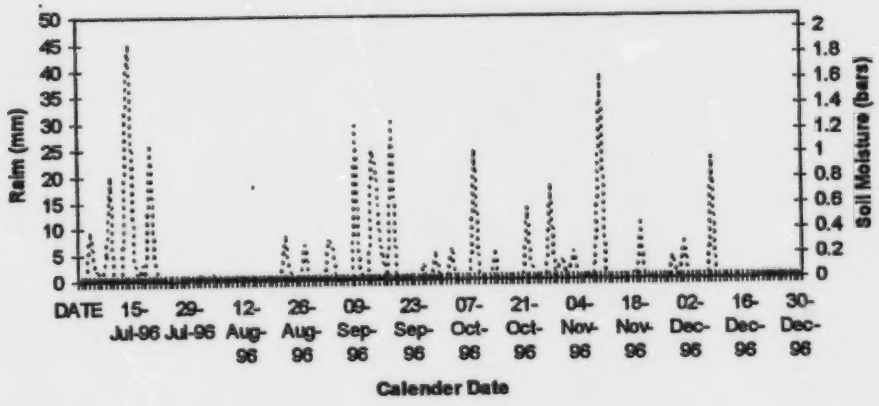


Figure 5. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 7 (location b) are shown as solid and dashed lines respectively (July 15/96 – December 30/96).

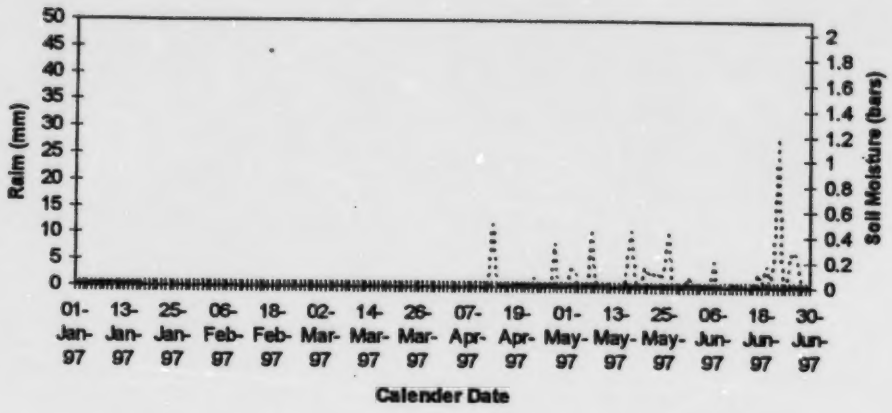


Figure 6. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 7 (location b) are shown as solid and dashed lines respectively (January 1/97 – June 30/97).

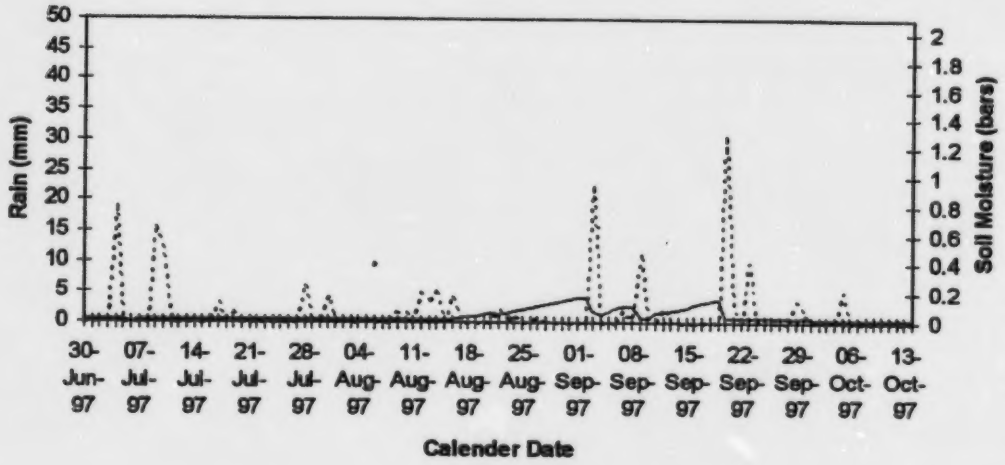


Figure 7. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 7 (location b) are shown as solid and dashed lines respectively.

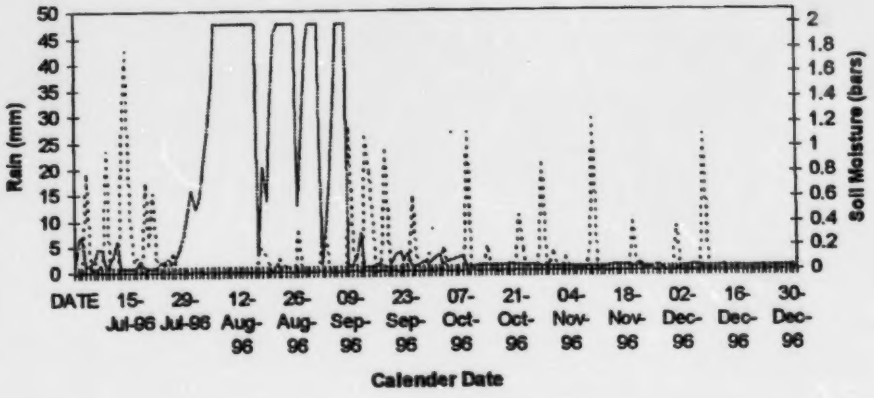


Figure 8. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 4 (location a) are shown as solid and dashed lines respectively.

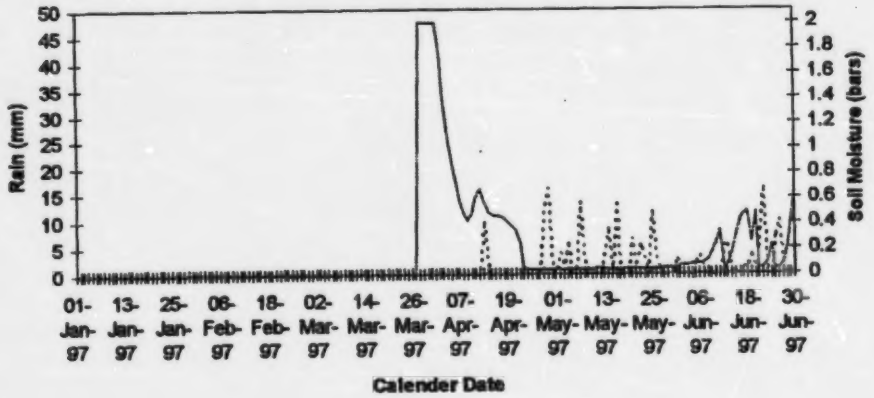


Figure 9. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 4 (location a) are shown as solid and dashed lines respectively.

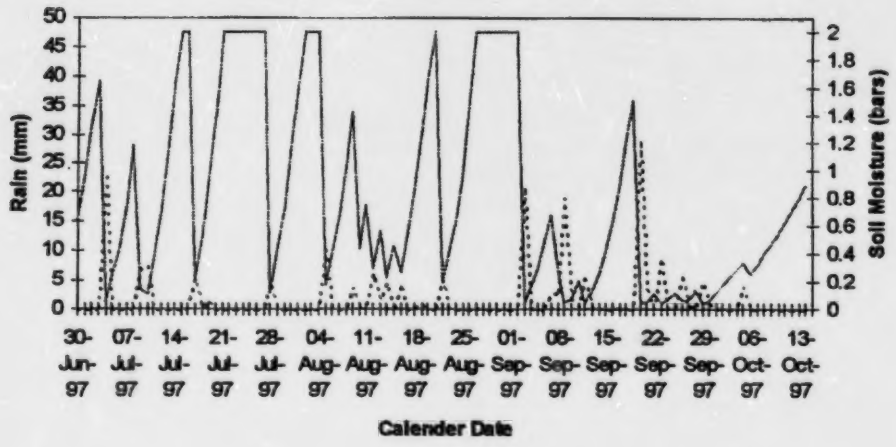


Figure 10. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 4 (location a) are shown as solid and dashed lines respectively.

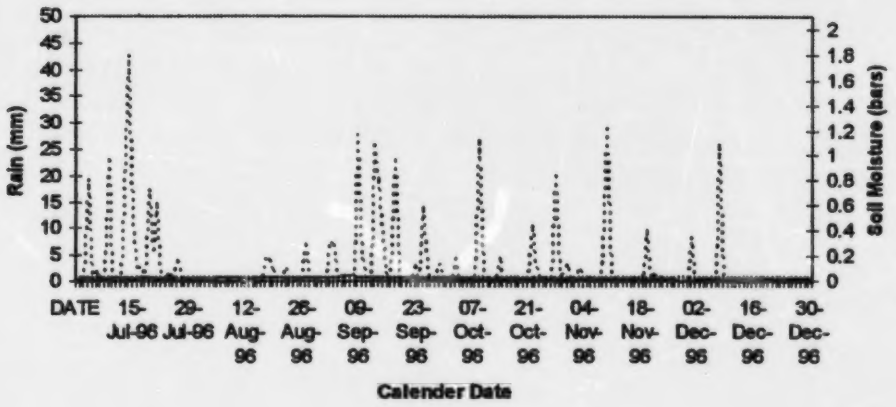


Figure 11. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 4 (location b) are shown as solid and dashed lines respectively.

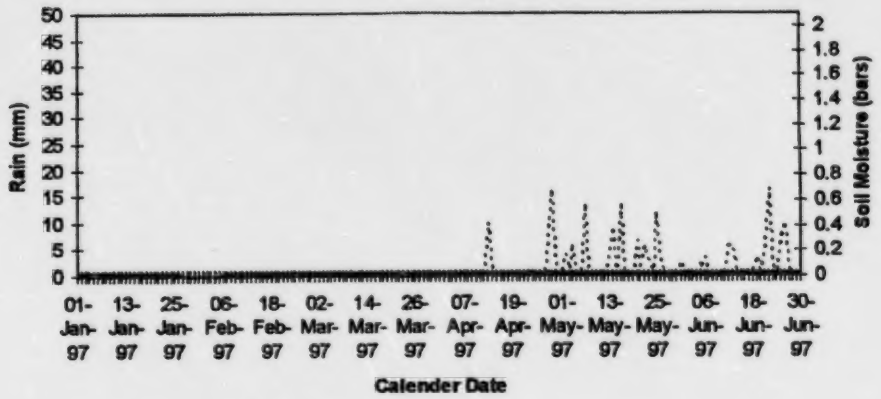


Figure 12. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 4 (location b) are shown as solid and dashed lines respectively.

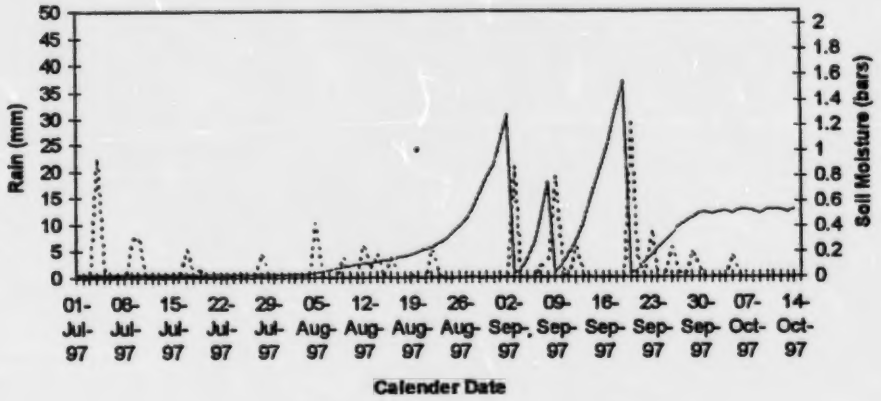


Figure 13. Soil Moisture (Water Potential Method) and Precipitation Measurements at Meteorology Station 4 (location b) are shown as solid and dashed lines respectively.

A.2 GROUND TRUTHING COINCIDENT WITH AN IMAGE

This portion of the report is devoted to the ground truthed information which was collected by the personnel at CFB Gagetown. It should be noted that ground truthing was not available for all of the image acquisitions and that the following ground truthed information was collected near the time that the satellite image was collected. This information is ordered historically. Note that any acronym or abbreviation can be found in a list at the end of this report.

As aforementioned in the introduction, the digital images are referenced by day and number. All other photographs have a DREO reference number associated with them. All photographs can be found in Appendix D.

Ground Truth Summary for Radarsat Image: May 09, 1996

Targets and Sites (See Table 12 below):

1. Artillery Convoy on Shirley Road
2. Track and wheeled vehicles at Hersey Bivouac
3. Vimy Range

Terrain :

1. Artillery Convoy on hard-packed, 9.75 m wide gravel road. Open fields to the SW.
2. Hersey Bivouc Site: Cleared area, with black track trail.
3. Vimy Range at Small Arms Range Complex: no information

Vegetation :

1. Artillery Convoy: Open field to the SW and mixed forest to the NE
2. Hersey Bivouc Site: - no information
3. Vimy Range at Small Arms Range Complex: Grassed area

Weather:

Sky, Temperature and Relative Humidity (RH) at time of image: Clear Skies, at 19:00 - RH 31%, 13.0° C; at 20:00 - RH 34%, 10.6° C;

Precipitation before and at time of satellite image : none.

Wind (at time of image) : at 19:00 - 26 km/hr; at 20:00 - 22 km/hr;

Soil : Dry

TARGET OR FEATURE	DETAILS	GEOGRAPHIC POSITION UTM-WGS84 DATUM	PHOTO ID#
Hersey Bivouc Site: Camp & vehicles	Tents, wheeled & tracked vehicles	45°49′ 38.5″ N, 66°15′ 48.3″ W 0712555 E, 5078508 N	7-9 (digital)
Vimy Range; Maidstone Rd	-	45°49′ 33.6″ N, 66°19′ 13.3″ W 0708139 E, 5078206 N	-
Artillery convoy; 3 M109s	Moving target	45°49′ 26.4″ N, 66°15′ 20.8″ W 0713162 E, 5078155 N	1-6 (digital)

Table 12. Ground truthed targets for Radarsat image : May 9, 1996. N/A represents not applicable and a dash (-) represents that there is no information.

Ground Truth Summary for Radarsat Image: May 16, 1996

Targets and Sites (See Table 13):

1. Firing Point 2: concrete pads
2. Truck Convoy : 2 x 5/4 trucks
3. Mobile Bath Unit: vehicles, tents, bridge
4. Cootes Bivouac Site: vehicle, tents
5. Camp Petersville: tents, buildings, vehicles
6. Blissville Bivouac Site: concrete pad

Terrain :

1. Firing Point 2: open field
2. Truck Convoy : on Maidstone Road which is hard packed gravel and 9.75 m wide
3. Mobile Bath Unit: parking lot / open field
4. Cootes Bivouac Site: open field (appears to be a large parking lot with mixed species tree stands at the edges, from photographs 10 & 11)
5. Camp Petersville: open field, grassy area with bare compacted soil
6. Blissville Bivouac Site : compact soil

Vegetation :

1. Firing Point 2: from photographs 1-3, it appears to be soil or gravel with grass in the distance
2. Truck Convoy : grassy area (20 m) from road to edge of brush and mixed species tree stands (trees beginning to bud)
3. Mobile Bath Unit: from photograph 9, parking lot is surrounded by a mixed forest
4. Cootes Bivouac Site: grassy area with dirt roads
5. Camp Petersville : grass
6. Blissville Bivouac Site : grass

Weather:

Sky, Temperature and Relative Humidity (RH) at time of image: 19:00 - RH 36%, 17.0° C with clear skies; 20:00 - RH 41%, 14.1° C with clouds moving in;

Precipitation before and at time of satellite image : none.

Wind (at time of image) : 19:00 - 31 km/hr; 20:00 - 23 km/hr;

Soil : Mostly dry; Some wet areas east of Maidstone Road

TARGET OR FEATURE	DETAILS	GEOGRAPHIC POSITION UTM-WGS84 DATUM	PHOTO#
Firing Point 2;	Concrete pad	45°48′ 57.7″ N, 66°25′ 27.5″ W 0700101 E, 5076835 N	1-3 (digital)
Convoy 50 m apart	2 x 5/4 truck	45°49′ 21.4″ N, 66°27′ 36.0″ W 0697303 E, 5077477 N	4-8 (digital)
Mobile Bath Unit-Bell Bridge & vehicles	APCs, trucks, ambulance	45°34′ 09.9″ N, 66°19′ 18.2″ W 0708987 E, 5049697 N	9 (digital)
Cootes Bivouac camp	Vehicle, tents	45°34′ 13.1″ N, 66°18′ 04.0″ W 0710592 E, 5049850 N	10-11 (digital)
Camp Petersville camp	Tents, buildings, vehicles	45°34′ 25.1″ N, 66°22′ 28.3″ W 0704850 E, 5050031 N	-
Blissville Bivouac site's pad	Concrete pad	45°36′ 21.1″ N, 66°32′ 45.9″ W 0691357 E, 5053186 N	-

Table 13. Ground truthed targets for Radarsat image: May 16, 1996. N/A represents not applicable and a dash (-) represents that there is no information.

Ground Truth Summary for Radarsat Image: 13 August, 1996

Weather:

Sky, Temperature and Relative Humidity (RH) at time of image: at 19:00 - RH = 51%, 19.0° C; [Met Station 1]

Precipitation before and at time of satellite image : none.

Wind (at time of image) : at 19:00 - 12 km/hr @ 183° True N [Met Station 1];

NO GROUND TRUTHING EXCEPT AIR PHOTOGRAPHS. SEE APPENDIX D

Ground Truth Summary for Radarsat Image: 6 September, 1996

Weather:

Sky, Temperature and Relative Humidity (RH) at time of image: hazy and overcast skies and 15° C

NO GROUND TRUTHING EXCEPT AIR PHOTOGRAPHS. SEE APPENDIX D.

Ground Truth Summary for Radarsat Image: December 11, 1996
See also: Appendix C, site 15: December 11, 1996

Targets and Sites (See Table 14 below):

Exercise site at Lawfield Bivouac area where several trucks and Howitzers were on site.

Terrain :

Moderate hilly area, directly off of Lawfield Road. The exercise was staged around a predominate hill in this region. From this hilltop, one can see a valley which is surrounded in the distance with other hills of about the same height.

Vegetation :

The top of the hill is bare from vehicle traffic. Further down the hill, grass followed by mixed deciduous tree stands are found. The entire surrounding valley is covered predominantly with mixed deciduous trees.

Weather:

Sky, Temperature and Relative Humidity (RH) at time of image : Cloudy Skies

Precipitation before and at time of satellite image : not available

Wind (at time of image) : not available

Soil :

Clay-sand-organic soil mixture with some sand and gravel pockets. There are some large stones (of glacial origins, most likely). At the time of the satellite image the soil was muddy and wet.

Metal culverts are dug into the side of the hill at a couple of sites near the hill top. Near the wrecked vehicle, there was shattered glass and metal fragments.

TARGET OR FEATURE	DETAILS	GEOGRAPHIC POSITION UTM-WGS84 DATUM	PHOTO ID#
LSVW	Muddy soil	45°42'28.66"N, 66°14'43.92"W 0714402E, 5065291 N	Digital 2-11
105 mm Howitzer	Muddy soil	45°42'26.67"N; 66°14'38.24"W 0714527 E, 5065234 N	Digital 2-11
MLVW	Muddy soil	45°42'26.67"N, 66°14'38.01"W 0714532 E, 5065234 N	Digital 2-11
105 mm Howitzer	Muddy soil	45°42'27.48"N, 66°14'36.94"W 0714554 E, 5065260 N	Digital 2-11
MLVW	Muddy soil	45°42'27.31"N, 66°14'36.31"W 0714568 E, 5065255 N	Digital 2-11
LSVW	Mud and grass	45°42' 27.2"N, 66°14'34.61" W 0714605 E, 5065253 N	Digital 2-11
105 mm Howitzer	Mud and grass	45°42'27.48"N, 66°14'34.08"W 0714616 E, 5065262 N	Digital 2-11
MLVW	Mud and grass	45°42'27.28"N, 66°14'32.71"W 0714646 E, 5065257 N	Digital 2-11
LSVW	Muddy soil	45°42'27.11"N, 66°14'32.16"W 0714658 E, 5065252 N	Digital 2-11
LSVW with trailer	Amongst trees, on mud	45°42'27.72"N, 66°14'29.17"W 0714722 E, 5065273 N	Digital 2-11
2.5 Ton Wreck*	Near tree stand on grass	45°42'27.98"N, 66°14'29.16"W 0714722 E, 5065281 N	Digital 2-11
LSVW with trailer	Grass surface	45°42'25.7"N, 66°14'28.7" W 0714734 E, 5065212 N	Digital 2-11

Table 14. Ground truthed targets and features for Radarsat image: December 11, 1996. N/A represents not applicable and a dash (-) represents that there is no information.

There were digital photographs available for this date (Nos. 2 – 19), which show this immediate area. Note, in digital photograph No. 11 (for Dec 11/96), the howitzer under a camnet with a supply truck about 10 m behind, is a typical configuration during exercise and combat conditions. The 105 and 155 mm howitzers are typically spaced about 35 and 50 m apart.

* Note that more truthing of this area and wreck are presented in: site 15, Appendix C.

Ground Truth Summary for Radarsat Image: February 16, 1998;

Targets and Sites (See Table 15 below):

1. camp with tents, M113s, trucks and bridge
2. buildings, excavater, bull-dozer and truck

Terrain :

Snow covered terrain; no more information.

Vegetation :

1. The area is surrounded with a forest consisting mostly of spruce and pines.
2. There is a nearby forest which contains spruce and birch.

Weather:

Sky, Temperature and Relative Humidity (RH) at time of image : Variable clouds, -4°C, dry, 46% RH.
Precipitation before and at time of satellite image : none
Wind (at time of image) : calm

Soil :

Snow cover (47 cm at Fredericton airport)

TARGET OR FEATURE	DETAILS	GEOGRAPHIC POSITION UTM-WGS84 DATUM	PHOTO ID#
M113, tent-10 man	-	45°34′ 17.4″N, 66°18′ 01.8″ W 0710635 E, 5049985 N	-
ski-doo	-	45°34′ 18.5″N, 66°18′ 01.7″ W 0710635 E, 5050018 N	-
M113	-	45°34′ 18.6″N, 66°18′ 00.9″ W 0710654 E, 5050021 N	-
Tent-10 man	-	45°34′ 18.5″N, 66°18′ 01.4″ W 0710642 E, 5050018 N	-
2 LSVW, MLVW, jeep	-	45°34′ 14.5″N, 66°18′ 03.6″ W 0710598 E, 5049895 N	-
Bell Bridge	-	45°34′ 16.7″N, 66°19′ 12.7″ W 0709098 E, 5049913 N	-
Building	-	45°50′ 36.5″N, 66°17′ 21.5″ W 0710485 E, 5080230 N	-
Building	-	45°50′ 36.8″N, 66°17′ 23.6″ W 0710439 E, 5080238 N	-
Excavator	-	45°50′ 33.2″N, 66°17′ 23.1″ W 0710454 E, 5080128 N	-
Bulldozer	-	45°50′ 32.0″N, 66°17′ 22.2″ W 0710474 E, 5080092 N	-
Truck	-	45°50′ 32.9″N, 66°17′ 22.4″ W 0710468 E, 5080119 N	-

Table 15. Ground truthed targets and features for Radarsat image: February 16, 1998. N/A represents not applicable and a dash (-) represents that there is no information.

Ground Truth Summary for Radarsat Image: March 12, 1998;

Weather:

Sky, Temperature and Relative Humidity (RH) at time of image : A few clouds, -12°C, dry, 38% RH.
Precipitation before and at time of satellite image : None at the time. There was a large rainfall on previous day(s) causing flooding in some locations.

Soil :

Snow cover is variable and ranges between 0 and 20 cm.

NO GROUND TRUTHING AVAILABLE

Note: Some flooding in the region occurred within a day or two prior to this image. Welshford Bridge was washed away in this flood.

APPENDIX B DREO GROUND TRUTH LOG

Below follows the ground truthing logs kept by DREO for quasi-stationary targets and scenes at CFB Gagetown during the time between September 29, 1997 and October 3, 1997. All targets and environmental features are highlighted in bold print. In this log, minor targets and environmental details are also documented. Additionally, notes about equipment problems and other relevant facts are recorded here. Note that the major sites briefly discussed in section 4 and referenced in the logs below, are documented in greater detail in Appendix C.

The ground truthing team included; Maureen Yeremy, Defence Scientist, Defence Research Establishment Ottawa (DREO), and Terry Potter, a contractor for the same establishment.

Log for September 29, 1997

09:00 - We met Halia Sushko, our contact person, and subsequently we were introduced to Major Brian Travis. We explained the project and discussed the type of scenes that we would like to truth. Major Travis was very helpful; he provided us with relevant information and an escort for when we were traveling through dangerous territory.

13:30 - We discussed previous ground-truthing experiments and possible sites to visit. We arranged for future meetings with DND Forestry and Major Douglas. We also acquired numerous maps containing environmental information and ground-truthing records which were collected when Radarsat images were acquired.

Log for September 30, 1997

08:00 - We met with DND Forestry (Pat Jones, Chief Forester) and they informed us of the various distinct habitats, tree stands and deforested areas at the base. They advised us that they may be able to arrange a helicopter flight for us over the region. Ron Trundell, a contractor in the Forestry Building helped escort us for the remaining day throughout CFB Gagetown. The following is a historical record of visited sites and environmental features for the day.

- **A Big Culvert** is located on Maidstone Road on the east side of the Small Arms Range Complex, near where Drummond Road intersects Maidstone Road.

- **Argus West Road** is a narrow gravel road which descends steeply towards the Company Defensive Position (COY DFF POSN). Mixed brush and forest stands are on both sides of the road.

- **Site 1; Company Defensive Position (COY DFF POSN)** (see Appendix C for truthed information)

- **Large Danger Sign**, of length 6 m, is found on Drummond Road between the telephone booths T2 and the Argus West Road.

- **Target Storage Buildings** are next to the South Boundary Road near the Rockwell Demolition site.

- **Grubbed area** on route towards Rockwell Demolition (grubbed, See definition in Section 2.1, Vegetation). Another grubbed area within following boundaries; Nerepis R, east of Drummond Rd and south of South Boundary Road.

- **Site 2; Rockwell Demolition** (see Appendix C for truthed information)

- **Site 3; Knowlton Hill** (see Appendix C for truthed information)

- **Site 4; Stone Quarry** (see Appendix C for truthed information)

- **Site 5; Heath and Black Spruce Stand** (see Appendix C for truthed information)

- **Large Mixed Forest** found near intersection of Shirley and Lawfield Roads.

- **Site 6; Engineers' Airstrip 1** (see Appendix C for truthed information)

- **Site 7; Engineers' Austere Village** (see Appendix C for truthed information)

- **Site 8; Cemetary and Castle Grenade Range** (see Appendix C for truthed information)

- CFB Gagetown; At the end of the day, we discovered that most of the digital images from the digital camera were lost.

Log for October 1, 1997

08:00 - Since we do not have an escort this day, we do not have access to very many locations on the base. We are restricted to inactive regions only. Below follows the list of sites visited in historical order.

- **Site 9; Petersville Supply and Fuel Area** (see Appendix C for truthed information)

NOTE; GPS readings took a relatively long time. The batteries were replaced after a few readings. After this, however, we were not able to get the GPS receiver to function again.

- **Worthington Road,** 2 km east of Petersville, there is a forest stand of mixed tree species of varying sizes and with some very large old pines. The upright poles along this road are not strung with wires.
- **Enniskillen Road** has power poles on the north side of the road. The terrain along this road consists of rolling hills.
- **Area 57,** north of Enniskillen Road is mostly a clearcut area.

- **Enniskillen (townsite);** South of Enniskillen Road, there is a black spruce stand. It is near the western edge of the Enniskillen townsite (just past the creek).

- **Hoyt;** Old rail beds and bridges are found near the Hoyt townsite.

- **Hoyt Station;** A wooden bridge about 15 m long with an aluminum roof is near Hoyt Station and Highway 101.

- **Highway 101** is, in general, a farming community where most of the buildings have aluminum roofs.

- Site 10; Blissville Airstrip (see Appendix C for truthed information)

- **Hydro-lines** along the cut-line near Hoyt are shown in photograph 97-1728. The cut line is near another road which branches off of Highway 101 near Hoyt. Grass and small brush are growing within the hydro cut-line area (see photographs 97-1727 and 97-1729). Small (2m) spruce trees and a few larger spruce trees (which appear to be planted) also grow in the cut-line area. At the edges of the cut-line are very large spruce trees. There is a gravel track leading to the cut-line from the road.

- Site 11; Red Pine Stands near Gate 68 (see Appendix C for truthed information)

- Site 12; Forest Fire Airplanes at Fredericton Airport (see Appendix C for truthed information)

Log for October 2, 1997

08:00 - We met with the Geomatics Department, University of New Brunswick to see their 3-D Visualization software and to discuss their research emphasis. Afterwards, we went to the base and continued ground truthing. Below follows the list of places visited in sequential order.

- Site Battle Scene Example at Vimy range ; Example of combat training exercise We took pictures of typical battle exercise configurations.

- Site AIR; Air photographs over the region taken from a helicopter See Appendix D where many environmental features, targets and infrastructures are captured with photographs. (Maureen Yeremy)

- Site 12; Forest Fire Airplanes on the tarmac at Fredericton Airport. See previous day. This site was revisited (Terry Potter) and security allowed for ground truthing behind the fences.

- Site 13; Military Vehicles on Display at CFB Gagetown's Entrance (see Appendix C for truthed information) visited by Terry Potter

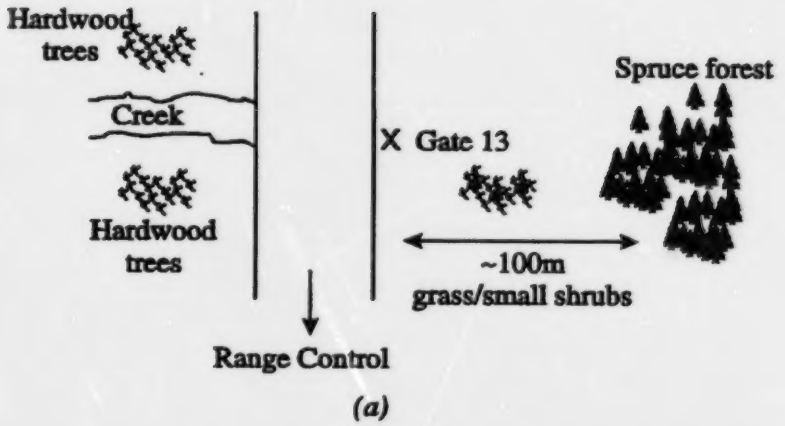
- Site 14; Gravel Pit near the north-east corner of the base (see Appendix C for truthed information)

Log for October 3, 1997

07:30 - We had reserved an escort, who would be able to take us to many otherwise inaccessible regions. Unfortunately we had a flat tire and a useless spare tire. We finally got another vehicle at about 11:00 am. We lost our escort, and were not able

to get another one until after lunch. Below follows the list of places visited, in sequential order.

- **Mixed forest / burnt forest remnants** was 1 km north of gate 15 on Highway 10.
- **Spruce stand** is found south of Shirley Road and slightly west of the base's gate 13. On the north side of Shirley road is a deciduous forest surrounding a creek which intersects with Shirley road. Figure 14a depicts the spruce stand relative to this creek, Gate 13 and Shirley road.
- **Spruce stand** is found south of Shirley Road (see Figure 14b) near the intersection of Shirley Road and the road towards Little Swan Bivouac region (found in CFB Gagetown's region 5).
- **Mixed forest** is found 1 km north of Gate 15 on Lawfield Road in region 10. It has regenerated from a 1986 forest fire, and is a mixture of species of varying sizes with large, charred tree remnants interspersed throughout the forest.



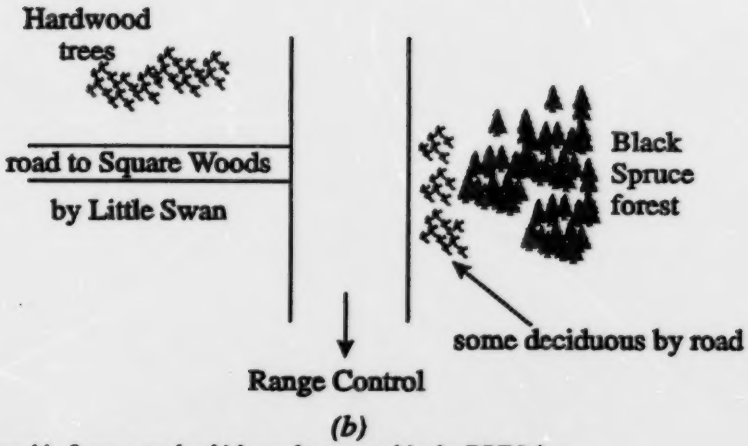


Figure 14. Spruce stands which are documented in the DREO log for October 3, 1997.

- **Nimble Barbara Exercise Area:** Battle exercises often occur here. The vegetation and terrain of this area are captured in the October 3, 1997 digital photographs 1 and 2. From the large parking area, directly off Lawfield Road, there are track trails into the mixed species tree and brush areas. There are some large pine trees (≈15 m, at 45° 44′ 33.79″ N 66° 12′ 52.44″ W) where the command post is often situated. There is a spruce stand (at 45° 44′ 33.26″ N, 66° 12′ 51.98″ W) about 200 m away (digital photograph 3, photographs 97-1920 and 97-1925). On the opposite side of Lawfield Road is a barren, grass covered impact zone.

- Meteorology_station # 4 - This meteorology station (see digital photographs 5 and 6, and Figure 15) is one of eight on the base. This station is surrounded by a metal link fence (16m x 15m). The main structure in the middle is a pole which has several devices (good corner reflectors) attached to it. Nearby are two smaller measurement instruments. This station can be approached from a side road which intersects with Lawfield Road. Further down the same side road is a sound ranging building. The local vegetation is predominantly grass and small shrubs. About 150 m away is a spruce stand. In the distant hillside, to the south-east of Lawfield road are mixed forest regions. Another stand of spruce is at the top of the hill at the edge of Victory Wood and near the base's gate 17, which is west of Lawfield Road. To the west of Lawfield Road is Lawfield Impact Zone, which is grass-covered. This zone has many bare patches that are likely due to shellfire.

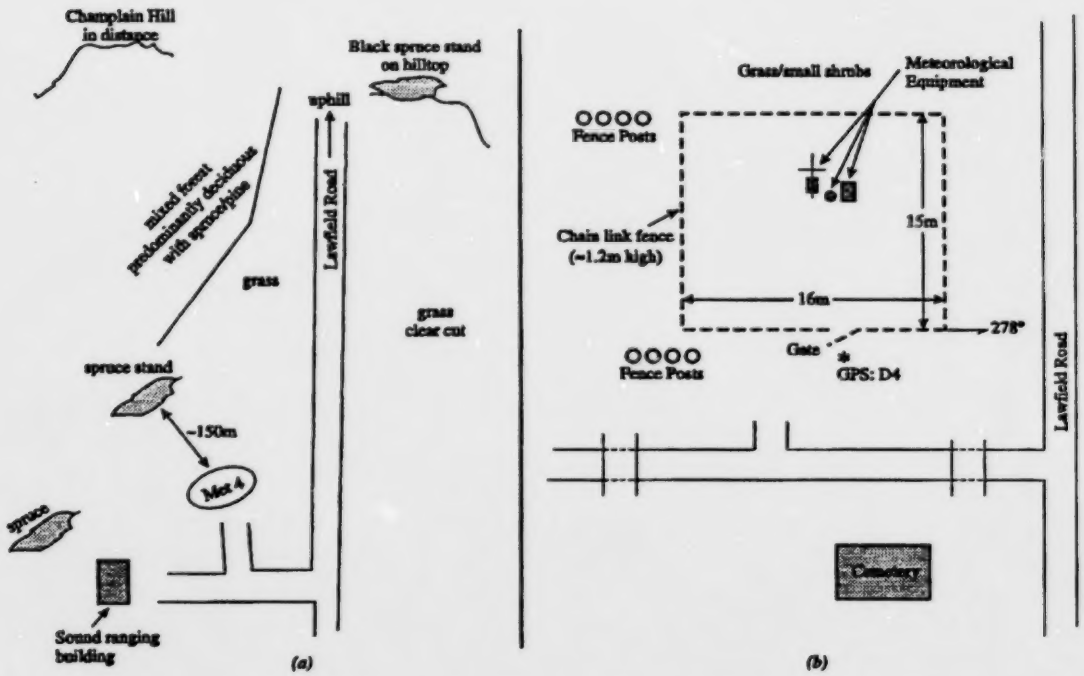


Figure 15 Meteorological Station 4 and the surrounding environment is shown in (a) and a close-up view of this station is shown in (b).

- Site 15; December 11, 1996 ground-truthed location (See Appendix A and C for truthed information)

- Gagetown townsite Photographs (97-1933 to 97-1935, at respective headings of south, east and north) of the surrounding waterways and islands were taken from the townsite's marina next to St John River. Across from the town is Gagetown Island, which is very marshy. Ducks Unlimited has maintained many of the marshland regions in the area, including part of Gagetown Island.

- Site 16; Transformer at Oromocto (See Appendix C for truthed information)

APPENDIX C DREO GROUND TRUTHING: STATIONARY SITE INFORMATION

This appendix contains the ground-truthed information for each major site visited during the DREO ground truthing at CFB Gagetown. This will include written documentation, sketches, measurements, photographic references, target headings, infrastructure and environmental information.

Both digital and film photographs for these scenes are contained in Appendix D and are referenced in the following manner; 1) digital photographs are referenced with the date and photograph number, and 2) all other photographs have a DREO reference number, x (which begins with the year as a prefix; e.g. 97-x). All the air photographs including geo-referenced photographs of the base are referenced in Appendix D.1 while all other photographs are referenced in Appendix D.2. The photographs are in Appendix D.3 with the digital photographs preceding the film photographs.

The ground truth information is organized in historical order in case there may be system errors (e.g.; GPS errors) which could be associated with a certain day and time.

Ground Truth Summary of Site 1: Company Defensive Position

Targets, Infrastructures and Distinct Environmental Features (see Tables 16 and 17) :

The main targets at this site includes an observational berm in the middle of a large gravel parking lot, a command post, several small dug-out bunkers with metal covers and mortar pits. The surrounding area was not accessible to us. It should be noted that in the surrounding area there are vehicles (mostly wrecked), bunkers, buildings, bridges and other structures. There were also "automated targets" which were fake targets that pop out of concrete bases when activated. These automated targets were installed in the summer of 1997 [These targets are known as: SIT, SVT, MVT and MIT, where the acronyms are made from; Stationary, Inventory, Vehicle, Moving, Target.]. More gravel roads and minor vehicle trails were also constructed in 1997. The bunkers were built in 1995. See Figures 16 to 19 and digital air photographs (August 16, 1996).

Terrain :

The command post and observation berm are at an elevated position centered within the middle of a group of hills. Figure 16 demonstrates the location of distinctive topographic features such as a swampy creek and gully near the command post, another creek in the distance and the grassy hills in the distance interrupted with tree stands.

Vegetation :

The vegetation in the immediate truthed area is generally grassy with shrubs. There is the occasional tree clump and alongside the nearby creek and gully, is a mixed stand of hardwood and softwoods with underlying brush.

Soil and Surface Litter :

The parking lot's surface is covered with well-graded gravel. There is a network of soil and gravel track roads throughout the region. These roads were not accessible to us. Some metallic debris on the surface was prevalent in the area.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PT	PHOTO ID #
Observation berm; GPS at centre	-	by gravel parking lot; wood & gravel steps on sides at mid-length;	23° berm heading	A1	-
Small bunkers	Metal lid covers, concrete walls	gravel surroundings	-	A2, A3	-
Opposite ends of berm	-	steep side (A4) and shallow side (A5, for vehicles)	23° berm heading	A4, A5	-
Circular mortar pit	Concrete	sand bags at edges; gravel surroundings	21° bearing from A1	A1	-
2 distant buildings	-	Inaccessible region	224°, 226° bearing from A1	A1	-
Command post entrance	Cement walls, roof	stairs down to underground building, sand bags along exterior walls & roof, grass and gravel at edges, near gully	64° heading facing door, 169° bearing from A1	-	-
Positions at edge of parking lot	-	gravel parking lot within these positions; tree clump inside	-	A6 to A12	-
Tree clump	A13 at mid-point	inside large gravel parking lot	-	A13	-
Sand bag pile & bunker near entrance	Maidstone Road entrance	-	Bearing of 258°, 256° from A1	A1	-
Distant tank	-	Inaccessible; nearby is soil, track paths, some grass.	Bearing of 125° from A1	A1	-
Distant scrap metal	-	Inaccessible	Bearing of 61°	A1	-
Distant large bunker	-	-	Bearing of 2°	A1	-

Table 16. Ground truthed targets at the Company Defensive Position. The GPS measurements are found below in Table 17 and the location of most of the GPS measurements are sketched in Figure 16. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE & LONGITUDE	UTM – WGS84 DATUM
A1	45° 46′ 41.6″N, 66° 24′ 58.4″W	700863 E, 5072653 N
A2	45° 46′ 42.4″N, 66° 24′ 57.3″W	700886 E, 5072679 N
A3	45° 46′ 42.8″N, 66° 24′ 58.1″W	700870 E, 5072691 N
A4	45° 46′ 42.4″N, 66° 24′ 58.5″W	700861 E, 5072679 N
A5	45° 46′ 39.3″N, 66° 24′ 58.0″W	700875 E, 5072583 N
A6	45° 46′ 38.1″N, 66° 24′ 57.8″W	700881 E, 5072546 N
A7	45° 46′ 37.0″N, 66° 25′ 0.3″W	700828 E, 5072510 N
A8	45° 46′ 33.5″N, 66° 24′ 59.9″W	700839 E, 5072404 N
A9	45° 46′ 31.6″N, 66° 25′ 0.6″W	700827 E, 5072344 N
A10	45° 46′ 33.6″N, 66° 25′ 3.2″W	700768 E, 5072404 N
A11	45° 46′ 40.3″N, 66° 25′ 8.6″W	700645 E, 5072606 N
A12	45° 46′ 40.5″N, 66° 25′ 1.0″W	700808 E, 5072619 N
A13	45° 46′ 41.2″N, 66° 25′ 1.1″W	700807 E, 5072640 N

Table 17. GPS Measurements at Site 1, the Company Defensive Position.

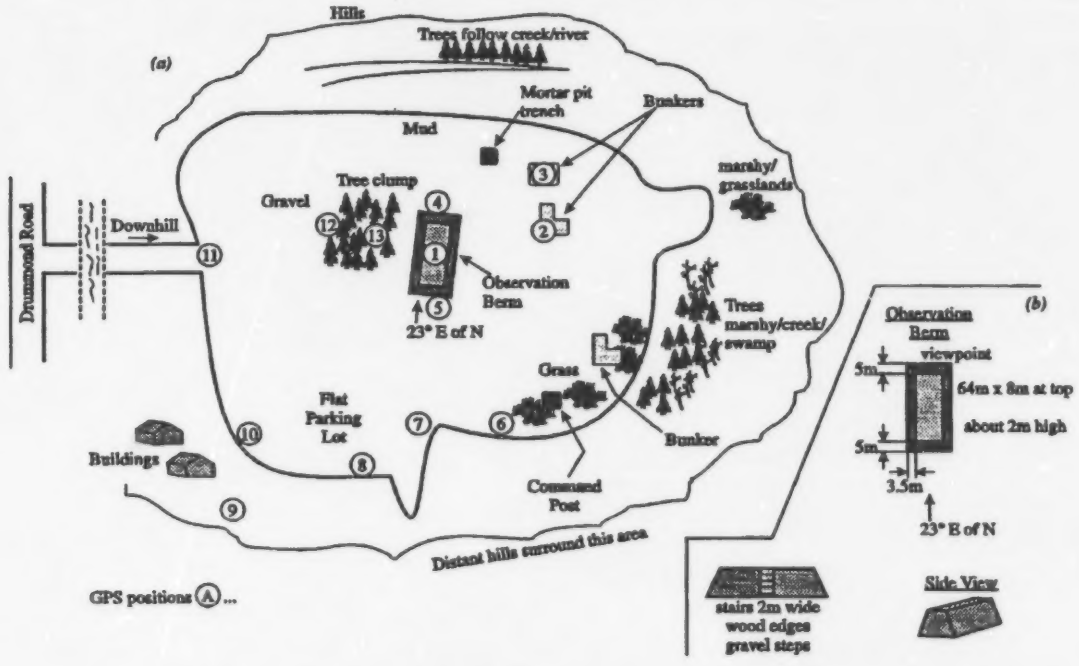


Figure 16. Company Defensive Position layout and GPS positions are shown to the left (a) while details of the berm are shown in the inset on the right (b). Note that the GPS positions referenced in Tables 20 and 21 are denoted here by the reference number only (e.g.; 15 instead of A15).

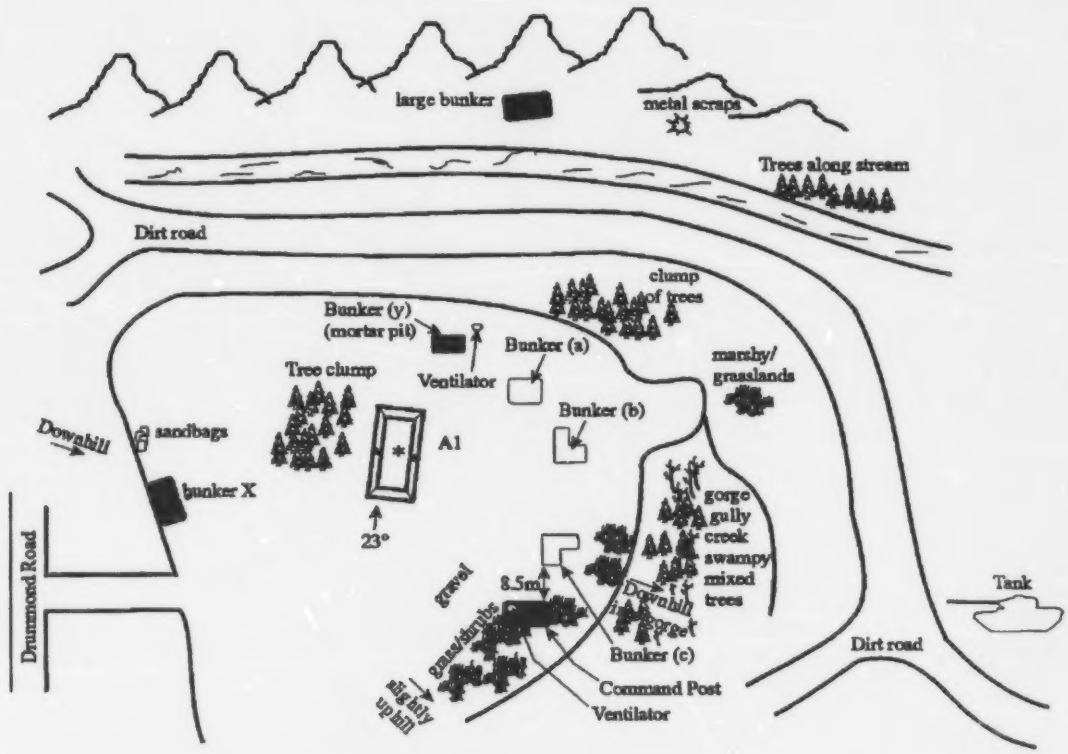


Figure 17. Targets at the Company Defensive Position.

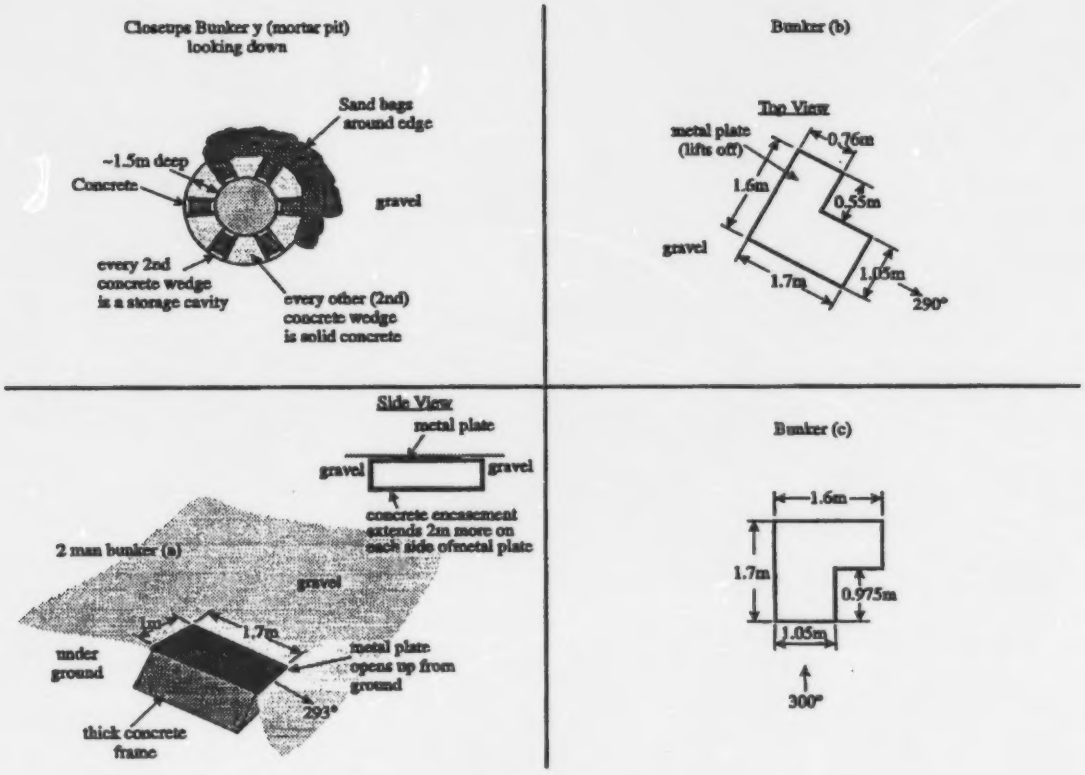


Figure 18. Bunker and mortar pit details at Company Defensive Position.

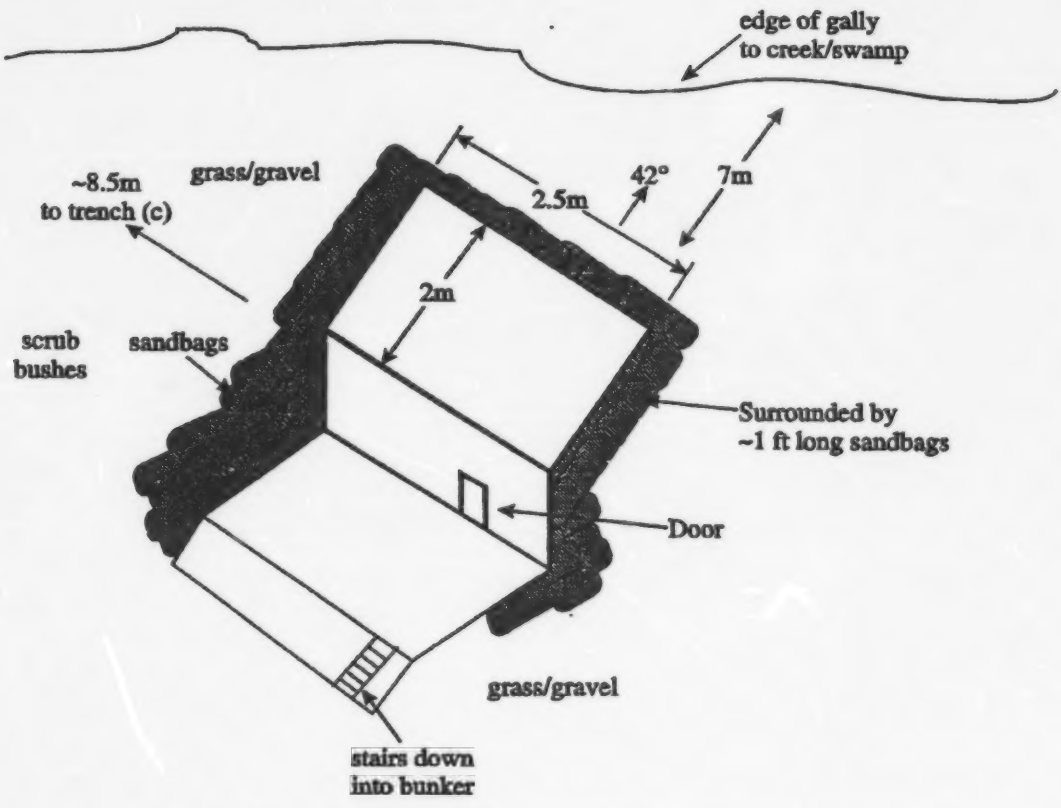


Figure 19 Close-up view of the command post at Company Defensive Position. Distances are approximate.

Ground Truth Summary of Site 2: Rockwell Demolition (now called Drummond Demolition)

Targets, Infrastructures and Distinct Environmental Features (see Tables 18 and 19) :

The main feature on the hill top is a large concrete bunker (10 ft x 15 ft) which is covered with a wedge of loose soil and gravel on three sides of the building. It was built around the beginning of 1997. The roof is about 30 cm thick and is made of concrete. The bunker is at the end of a gravel road. About 200 m from the bunker, are 2 large concrete shapes with the longest side length of about 1.2 m. One of the concrete figures has 6 sides and is surrounded at 4 corners with 4 metal poles (about 125 cm high) which are separated from each other by about 125 cm. Another square concrete shape is further down the hill and road. There was a bulldozer near the site on the approaching road, when we truthed the area. Since our visit in October, 1997, we have been informed that more changes have been made to this area.

Terrain :

The Rockwell site is at the top of a large hill. It has a commanding view of the region since from this vantage point, one can view the valley in front of it and the surrounding mountains in the distance. The approaching road and parking lot at the hill top is a mixture of soil and gravel.

Vegetation :

Below and on the same hillside where Maidstone Road approaches the site, the land is deforested and grubbed (with the exception of a few small tree stands a few hundred metres from the bunker). This area was clear-cut in 1995. The opposite hillside is still forested.

Soil and Surface Litter :

The soil probably had a lot of clay content judging from its dark and muddy appearance. Gravel was mixed in with the soil.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Large bunker	Concrete building	Gravel and soil surface; Sides covered with a wedge of loose soil & gravel	160° heading facing door	A14	-
Concrete shapes	Hexagon & pyramid shaped structures	Grass and bare soil with gravel;	-	A15 & A16	-

Table 18. Ground truthed Targets and Region at Rockwell Demolition GPS measurements are in Table 19. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE & LONGITUDE	UTM – WGS84 DATUM
A14	45° 42′ 33.0″N, 66° 21′ 59.7″W	704975 E, 5065107 N
A15	45° 42′ 35.4″N, 66° 22′ 0.4″W	704957 E, 5065181 N
A16	45° 42′ 35.6″N, 66° 22′ 1.4″W	704937 E, 5065187 N

Table 19. GPS positions at site 2. See Table 18 and Figure 20.

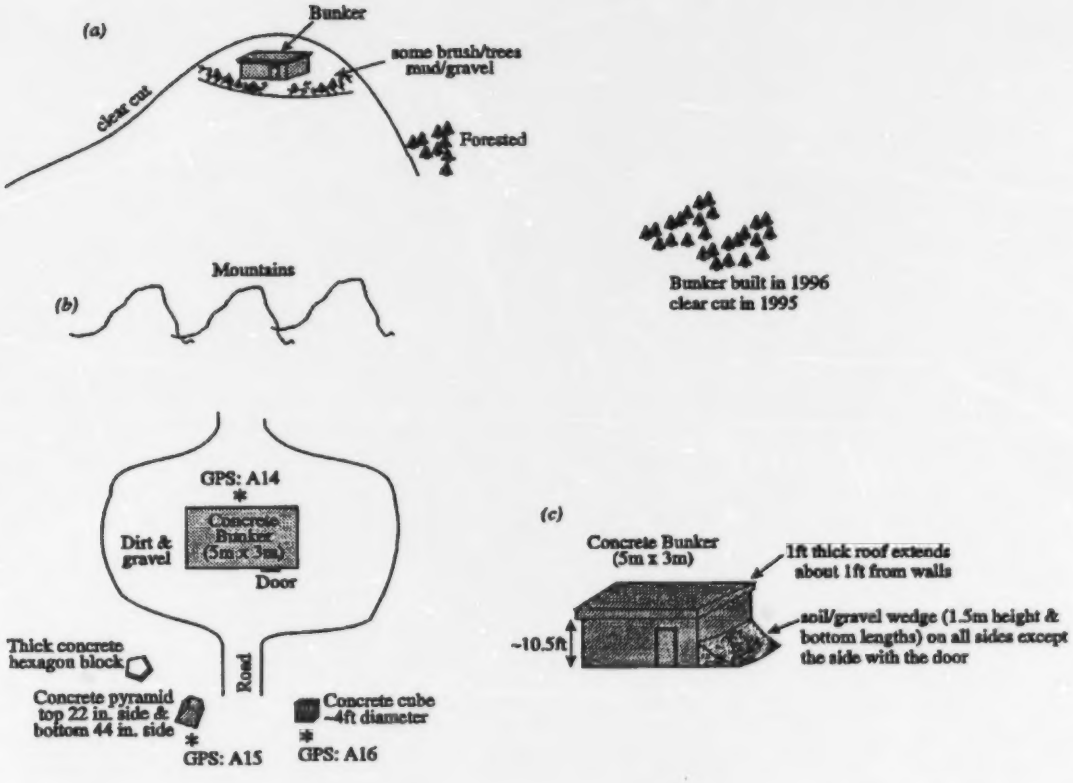


Figure 20 The upper left corner (a) is a perspective view of the bunker location while the lower left corner (b) is looking down onto the bunker. The lower right corner (c) shows a close-up view of the bunker. The lengths are approximate.

Ground Truth Summary of Site 3: Knowlton Hill

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Tables 19 and 20):

The main features at this site include a large tower, a building and a fuel tank (see Figures 21 and 22) which are enclosed within a metal chain link fence (15m x 24m). Outside of the fenced area is another large cylindrical storage tank (about 2 m long) and a large glacial rock (circular shape with approximate diameter of 2 m). The tower, according to one map is about 33 m long. There are wooden boardwalks littered randomly in this region. The approaching road loops around this site. Power lines/poles are found along the side of the road and end here at this site. A solar collector is on the roof of the building

Further down the hill slope, and on another side from the tower, is a small cemetery which is maintained by the base. This cemetery is surrounded by a metal mesh fence, 2 large trees and rocks piled against this fence. The surrounding hillside is almost entirely grubbed.

Terrain :

The site is at the top of Knowlton hill which is about 180 m high. The site overlooks a valley which is forested and is opposite to the approaching road.

Vegetation :

Small brush and trees are near the tether lines holding the tower (Figure 21). There are a few small tree stands (hardwood and softwood sections shown in Figure 21) a few hundred meters from the tower and buildings, which are about 6 to 8 m high. The birch stands contain spindly trees with diameters of about 10 cm and a tree density of about 5 trees/m^2. In contrast the spruce stand has tree diameters of about 20 cm with densities of about 3.5 trees/m^2. Most of the hill, on the side of the approaching road, is deforested and grubbed. In the valley where the road approaches this site, a ribbon of forested area exists; most likely because a creek is in the near vicinity. The opposite hillside's valley viewed from the top of the site is forested. Many of the remaining forest stands on Knowlton Hill are Commercially Thinned (CT) forests.

A cemetery (Figure 23) is located a short distance down the hill from the bunker. There are 2 large trees at the cemetery, both about 10 - 12 m high. The birch tree has a diameter of about 45 cm while the spruce tree has a diameter of about 30 cm.

Soil and Surface Litter :

The soil probably had a lot of clay content judging from its dark and muddy appearance. The road which approaches the tower is made from a gravel and soil mixture. Bare soil, due to grubbing was prevalent along the hillside which followed the approaching road. There were strewn wooden boardwalks laying randomly on the ground at the tower site.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Storage gas tank	Outside fence	on grass, gravel	-	A17	-
Propane tank, position from fence-side	Inside fence	grass, gravel, some small brush	Facing the broad side at 143°	A18	-
Tower, position from fence-side	-	grass, gravel, some brush	-	A19	-
Boulder	2m diameter	on grass	-	A20	-
Cemetery	-	soil, grubbed area surroundings	Facing gate at 248°	A21	-

Table 20. Ground truthed targets and features at Knowlton Hill. GPS measurements are in Table 21. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE & LONGITUDE	UTM – WGS84 DATUM
A17	45° 39′ 8.7″N, 66° 21′ 29.0″W	705847 E, 5058824 N
A18	45° 39′ 8.6″N, 66° 21′ 28.2″W	705864 E, 5058823 N
A19	45° 39′ 8.5″N, 66° 21′ 27.7″W	705876 E, 5058820 N
A20	45° 39′ 9.5″N, 66° 21′ 25.3″W	705927 E, 5058852 N
A21	45° 39′ 11.9″N, 66° 21′ 10.4″W	706246 E, 5058938 N

Table 21. GPS positions at site 3, Knowlton Hill. See Table 20 and Figures 21, 22 and 23.

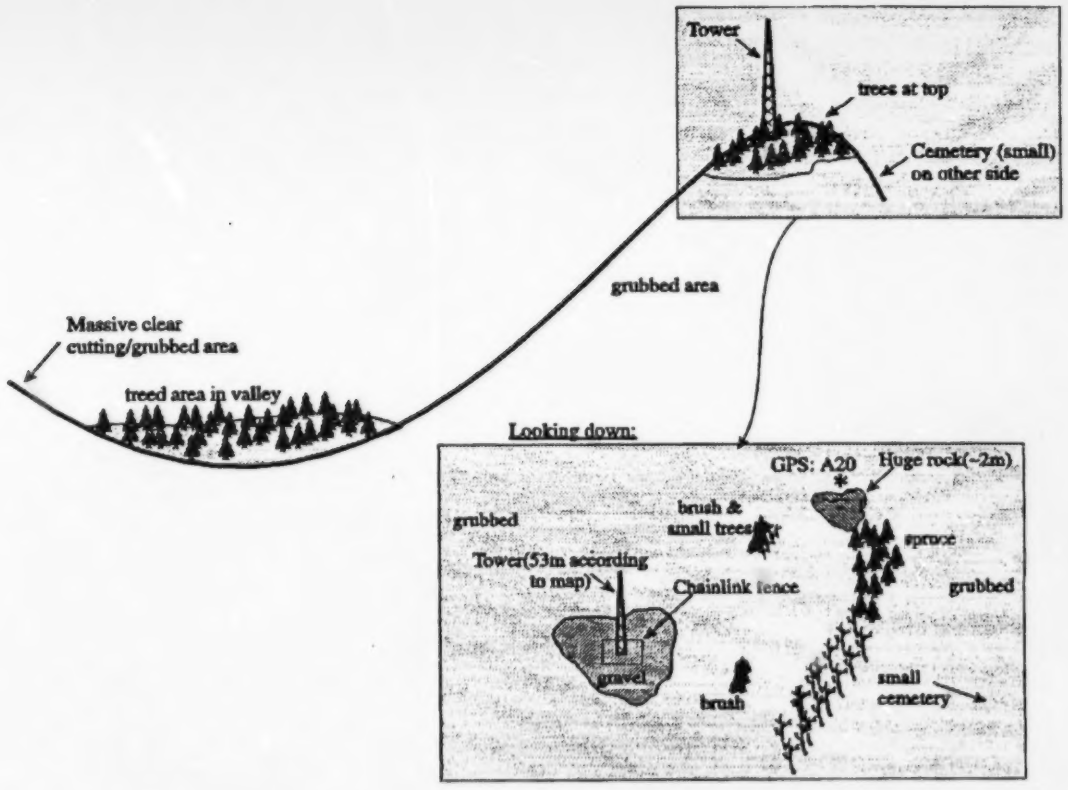


Figure 21 The upper diagram shows the overall environment while the lower inset is looking down over the tower and its surroundings.

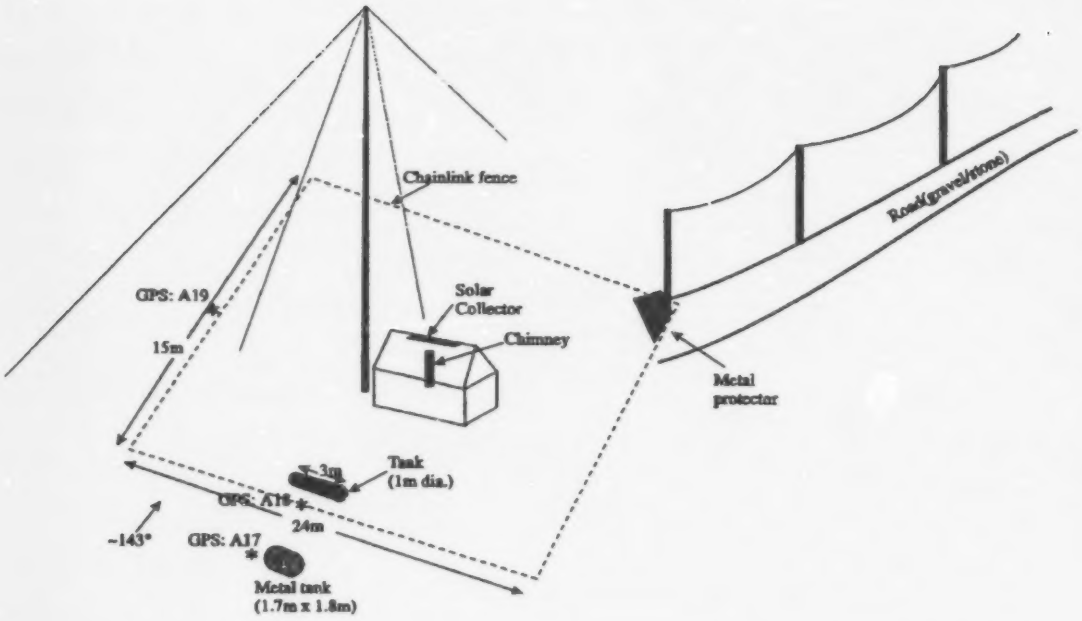


Figure 22 Close-up view of the tower and its immediate surroundings on top of Knowlton Hill.

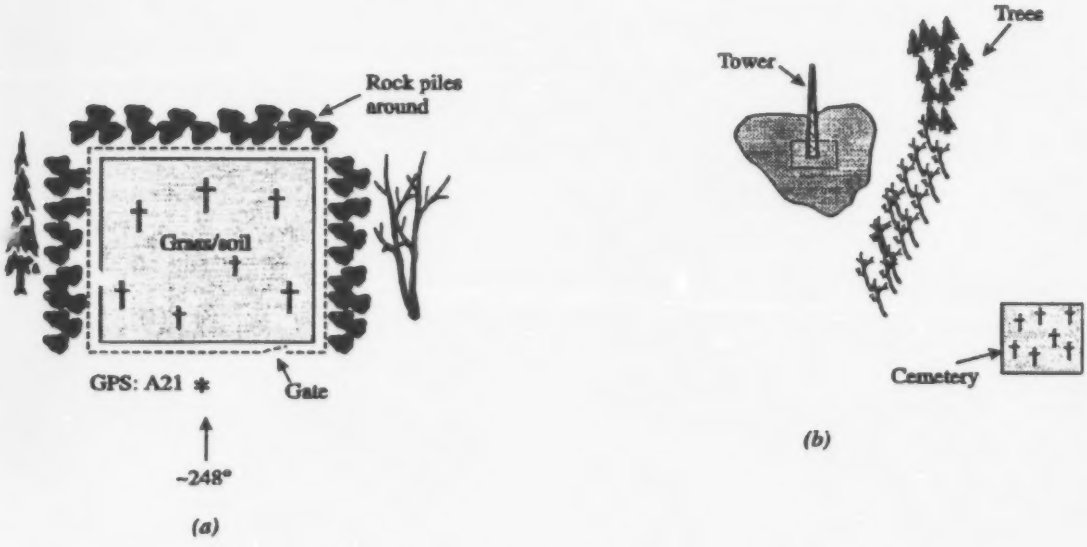


Figure 23 The cemetary is shown on the left side (a) and a perspective view (b) of the cemetary relative to the tower is shown on the right side.

Ground Truth Summary of Site 4: Stone Quarry

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Table 22) :

The main feature of this site is the rock quarry (Figure 24). Above this hill is a parking lot which was not ground truthed. The rock quarry was an excavation into the hillside, which exposed 3 underlying and distinct geological layers. At the base of the quarry it is flat and covered with gravel except for a few small gravel piles. A gravel road connects this quarry to Drummond Road. There were no GPS measurements acquired. However, the geographic location estimate is; 45° 46′ 26.2″ N, 66° 26′ 17.6″ W or 699170 E, 5072123 N and this is derived from a geo-referenced image.

Terrain :

In general, the topographic description of the area is gentle rolling hills. The quarry is located alongside a gravel road which stems out from Drummond Road.

Vegetation :

The hill is forested except for the quarry, the road going up the road and the parking lot at the top of the hill. Beside these man-altered features, the vegetation is mostly a combination of grass, small shrubs and trees. At further distances the area is forested with mixed species and sizes up to 10 m.

Soil and Surface Litter :

The exposed soil is generally gravel.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Stone quarry and region	-	on gravel	126°	mid-point	30/9-29
as above	Uphill slope	on gravel	179°	mid-point	30/9-30
as above	As above	on gravel	225°	mid-point	30/9-31
as above	-	on gravel	241°	mid-point	30/9-32

Table 22. Ground truthed targets at the Stone Quarry. N/A represents not applicable and a dash (-) represents that there is no information.

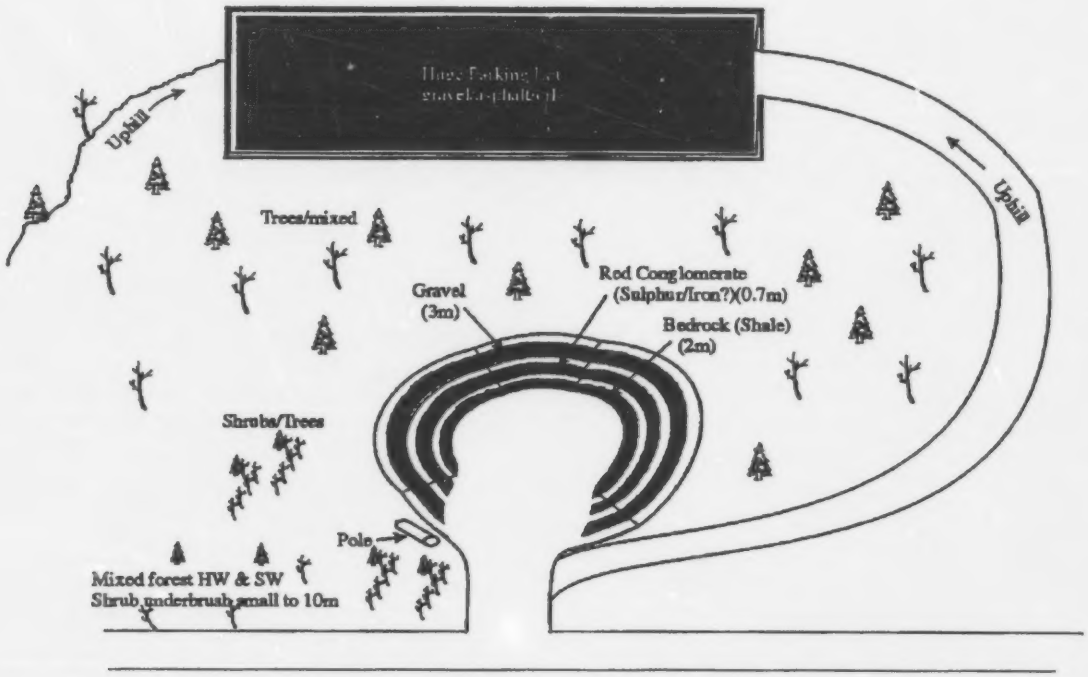


Figure 24. Depiction of the ground truthed Stone Quarry, or site 4.

Ground Truth Summary of Site 5: Bog Meadow, Spruce & Pine Stands

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Tables 23 and 24):

The bog begins from the edge of Drummond Road (Figure 25) and extends for a vast distance away. The bog begins just north of the intersection of Drummond and South Boundary Road and its extent could not be truthed because of trafficability problems. Photograph 97-2489 is a geo-referenced photograph, which shows the delineation of the wetland bog and forested regions quite well. Near Drummond Road and the bog is a large spruce stand and a small pine stand which are sketched in Figure 25. Both forest stands are within military inaccessible areas.

Terrain :

The area is somewhat flat. The matted underbrush here has a surface roughness texture similar to typical peat bog regions with respective roughness length and height of about .6 m and 0.2 m. The bog was extremely soggy and the surrounding thicketed area was very difficult to walk through. Along the distant bog edges are gentle-sloped and forested hillsides, with deciduous trees at the higher levels and spruce stands in the valley. A creek flows where the bog intersects with Drummond Road.

Vegetation :

The peat bog is covered with lush, matted and dense vegetation. It is surrounded immediately by very thick scrub brush and trees. Grass is near the roadside.

The spruce and pine stands are depicted in Figure 25 and Photograph 97-2489 and could not be ground truthed because they were inaccessible regions.

Soil and Surface Litter :

The area had a very wet muskeg appearance with at least one stream running through the middle of the region.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Bog	-	from roadside looking towards the heath's midpoint	326° camera heading	A22	97-1695
Bog	-	from side of thicket	240° camera heading	10 m N of A22	97-1696

Table 23. Ground truthed regional information of the heath along Drummond Road. GPS measurements are in Table 24. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE & LONGITUDE	UTM – WGS84 DATUM
A22	45° 41′ 41.3″N, 66° 22′ 43.6″W	704079 E, 5063481 N

Table 24. GPS positions for the bog and forest stands at site 5. See Table 23 and Figure 25.

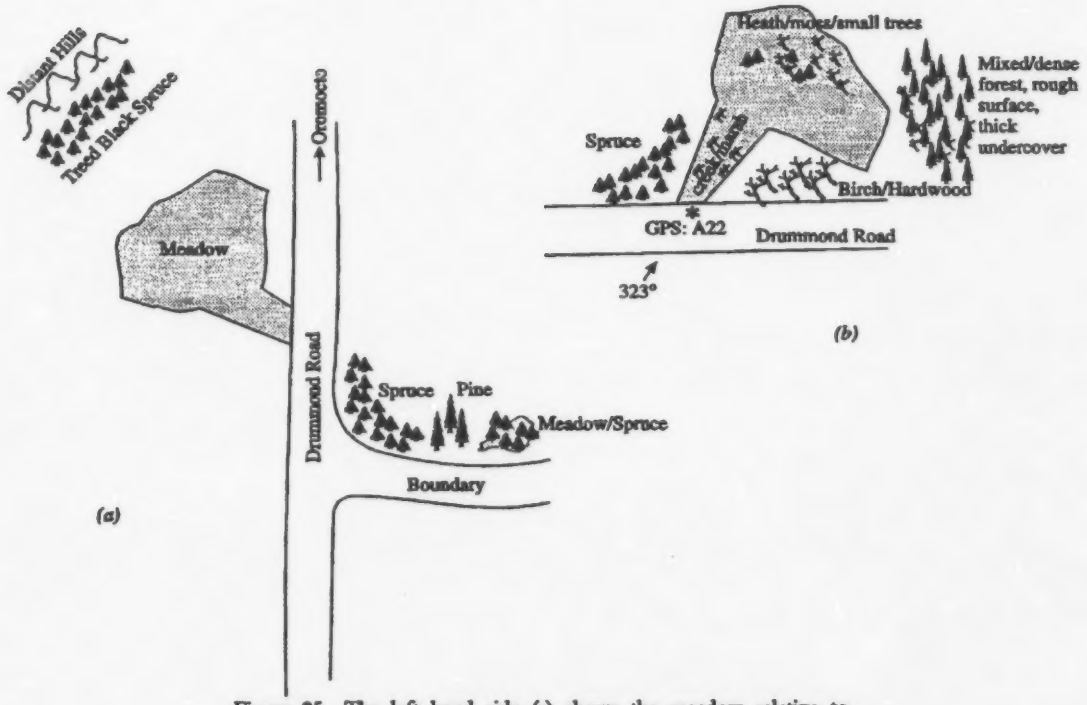


Figure 25 The left hand side (a) shows the meadow relative to geographic landmarks while the upper right hand side (b) is a close-up depiction of the meadow region.

Ground Truth Summary of Site 6: Airstrip 1

Infrastructures, Targets, Buildings and distinct environmental features (see Tables 25 and 26) :

An airstrip is near Shirley Road and a small uninhabited village (see Site 7). Both the airstrip and the village were designed by the base's engineering school and then subsequently built. This airstrip has many surface types, which include; concrete, tarmac and gravel (red and gray). Some portions were in the process of being built when we were there. There are ditches alongside some of the runway. Within a short distance of the runway are connecting gravel roads, a few buildings, fenced storage areas, a small transformer box (≅ 1 m high, on concrete platform with 4 ft metal poles near each corner) and an array of large wooden poles. The airstrip's length is about 0.7 km. Because of the construction at this site, there are many transient vehicles and targets at this location.

Terrain :

The area is very flat.

Vegetation :

Near the airstrip, is grass and small brush vegetation. There are tree stands a short distance (about 100 m) away which consists of mixed species and sizes.

Soil and Surface Litter :

The airstrip has various surfaces as is shown in Figure 27. The surrounding region's surface had the appearance of well drained soil. Construction materials littered the immediate region.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Airstrip	-	Edge of concrete surface, under construction in places	247° photo heading	A23	97-1698
Airstrip	-	Edge of gravel surface	258° photo heading	A23	97-1699
Airstrip	-	Transition between concrete and tarmac surfaces	248° photo heading	A24	97-1700
Airstrip	-	Looking down runway	92° photo heading	-	97-1701
Airstrip building	-	Looking from runway	170° photo heading	-	97-1702
Airstrip	-	End of tarmac surface	N/A	A25	-
Gravel road	-	Gravel road away from airstrip near end of the tarmac surface	N/A	A26	-
Gravel road	-	Corner 1 of attached gravel road	N/A	A27	-
Gravel road	-	Corner 2 of attached gravel road	N/A	A28	-
Gravel road	-	Attachment near interface of tarmac & concrete surface	N/A	A29	-
Transformer	-	Green metal transformer box	48° photo heading	A30	97-1703
Array of poles	-	In distance	107° photo heading	-	97-1704

Table 25. Ground truthed targets at Airstrip 1. The GPS positions are given below in Table 26. N/A represents not applicable and a dash (-) represents that there is no information.

GPS	LATITUDE & LONGITUDE	UTM – WGS84 DATUM
A23	45° 50′ 5.3″N, 66° 17′ 35.6″W	710212 E, 5079256 N
A24	45° 50′ 4.8″N, 66° 17′ 49.8″W	709908 E, 5079232 N
A25	45° 50′ 4.5″N, 66° 17′ 59.0″W	709708 E, 5079216 N
A26	45° 50′ 4.2″N, 66° 17′ 57.1″W	709749 E, 5079209 N
A27	45° 50′ 3.3″N, 66° 17′ 56.2″W	709771 E, 5079181 N
A28	45° 50′ 3.5″N, 66° 17′ 49.7″W	709911 E, 5079192 N
A29	45° 50′ 4.5″N, 66° 17′ 49.4″W	709917 E, 5079221 N
A30	45° 50′ 2.3″N, 66° 17′ 58.6″W	709719 E, 5079146 N

Table 26. GPS positions for site 6, Airstrip 1. See Table 25 and Figure 27.

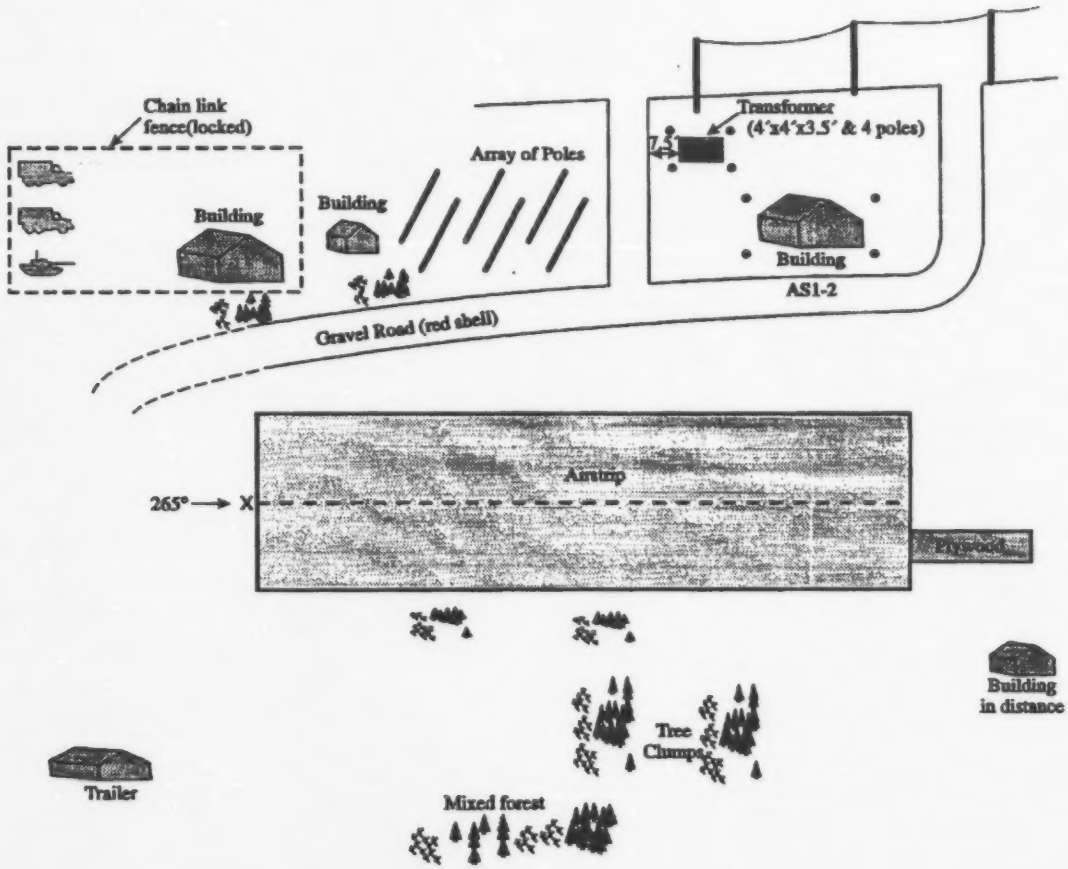


Figure 26 Overview of Airstrip 1 and the surrounding region.

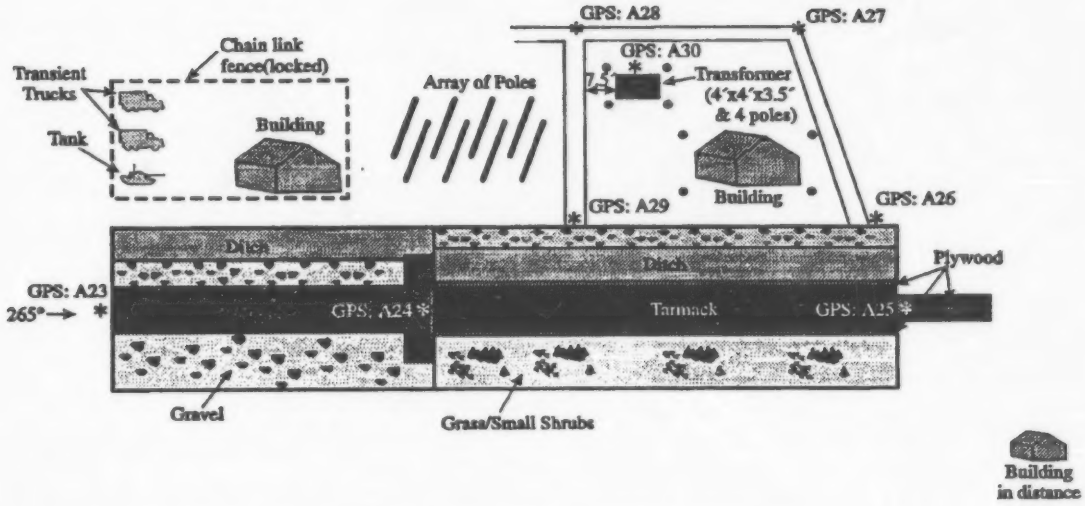


Figure 27. Details of Airstrip 1 and surrounding infrastructure. GPS positions are referenced in Tables 25 and 26. The airstrip length is about 0.7 km long.

Ground Truth Summary of Site 7: Engineers' Austere Village

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Tables 27 and 28):

An uninhabited village is near Shirley Road and the airstrip (Figure 28 and 29). It consists of a few houses as well as the infrastructure (e.g.; gravel and paved roads). We were not able to enter the fenced area, but a surveyed map (Figure 28) of the development, provided by the Surveying Department at CFB Gagetown shows the location of these homes. They also provided us with the following geographic locations in reference to Figure 28;

- position where the two side roads from Shirley Road intersect is :
  45° 50′ 10.1″ N, 66° 18′ 14.1″ W or E 709376.08, N 5079375.63
- position where a side road branches off towards the development's front gate :
  45° 50′ 06.5″ N, 66° 18′ 10.7″ W or E 709454.23, N 5079269.08
- position at the NW corner of building AV-1 is :
  45° 50′ 04.5″ N, 66° 18′ 14.4″ W or E 709376.48, N 5079201.92
- position at the SW corner of building AV-1 is :
  45° 50′ 03.8″ N, 66° 18′ 14.5″ W or E 709375.89, N 5079189.94

Building AV-1 is 8m x 12 m and the concrete driveway in front of it is 40 m long and centered on the building. The elevation at this building is 32.19 m.

Terrain :

The development is near Airstrip 1 and Shirley Road. At the entrance, the terrain is flat, but the village extends to the edge of a hillside or gully, where Swan creek exists.

Vegetation :

Near the village most of the tree stands have been removed and the vegetation is mostly grass.

Soil and Surface Cover:

There were no soil exposed areas. The region appeared to be well drained. There were large covered cylindrical bundles about 2 m long and .8 m in diameter littered around the village.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS, GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Austere village	Garage	grass covered	251° camera heading	A31	97-1705
Austere village	Garage	Grass covered	249° camera heading	A31	97-1706
Austere village	Homes	Grass covered	299° camera heading	A31	97-1707
Austere village	Homes	Grass covered	320° camera heading	A31	97-1708
Austere village	Homes	Grass covered	329° camera heading	Γ, fence corner in Fig 29	97-1709

Table 27. Ground truthed targets at the Austere Village. GPS measurements are in Table 28. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE & LONGITUDE	UTM – WGS84 DATUM
A31	45° 50′ 6.2″N, 66° 18′ 11.2″W	709444 E, 5079257 N

Table 28. GPS positions at site 7, the Austere village. See Table 27 and Figure 29.

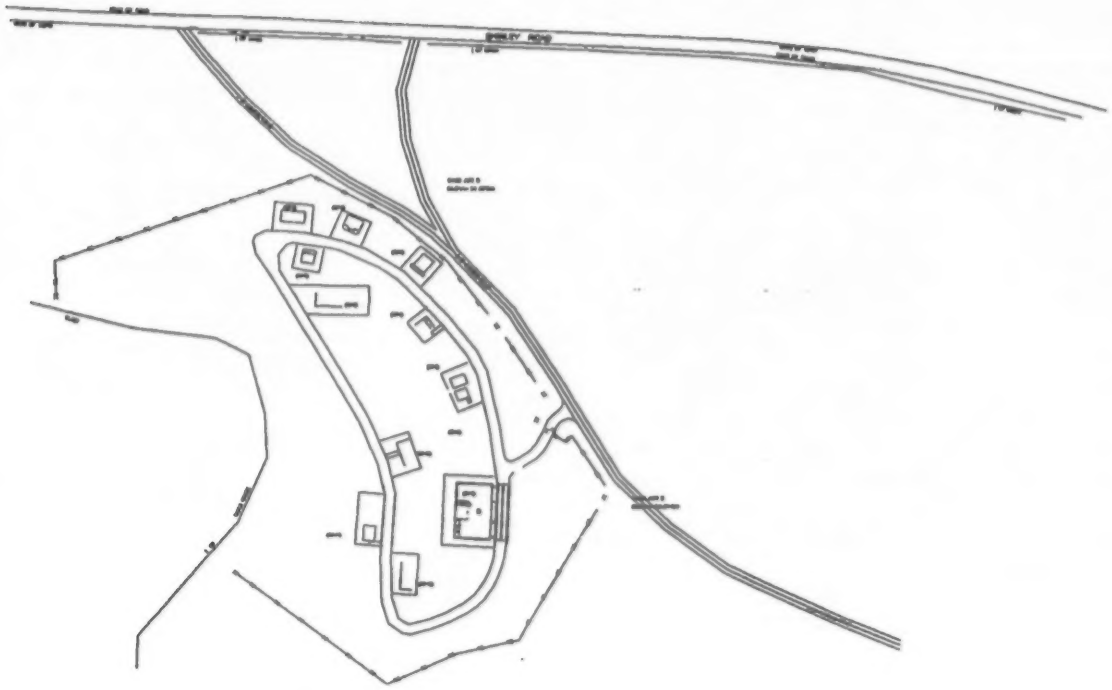


Figure 28. Survey drawing of site 7, the Austere Village.

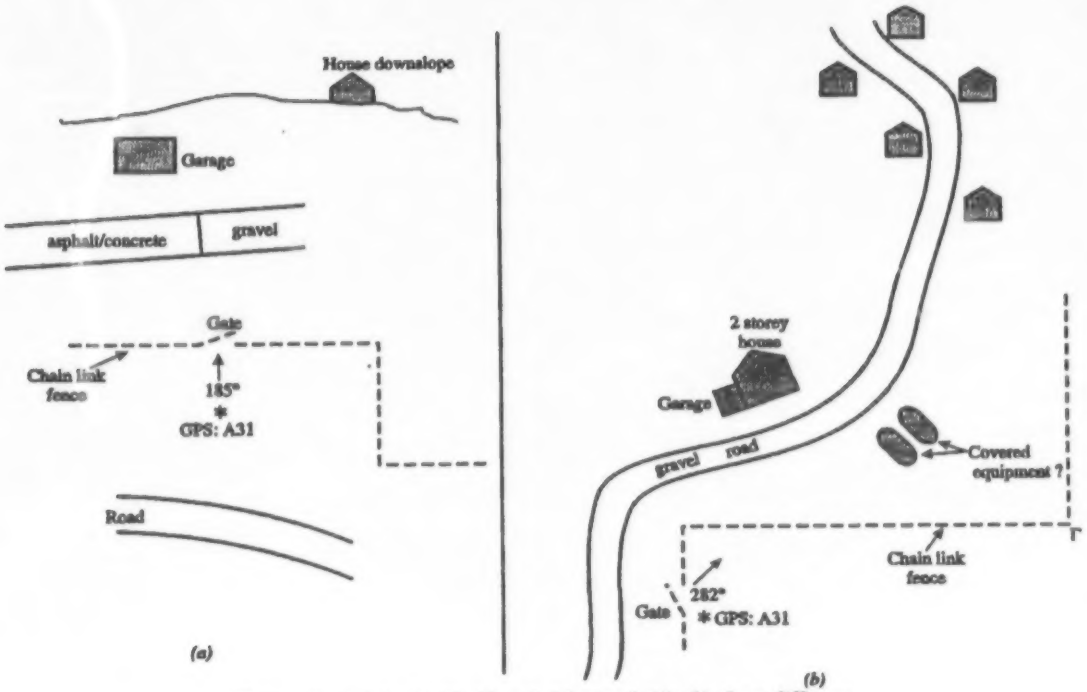


Figure 29 Left hand side (a) and right hand side (b) show different views of the Austere Village. The gate shown in (a) and (b) is the same gate. See Table 28 for GPS positions.

Ground Truth Summary of Site 8: Cemetery and the Castle Grenade Range

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Tables 29 and 30):

A large cemetery is approached from Shirley Road (Figure 30) and it is located on the opposite side of the road from the Castle Grenade Range. [The Castle is an inaccessible region, which can be viewed from the roadside.] This cemetery is fairly large (about 40 tombstones dating from 1830 to 1992) and is well maintained. The cemetery is surrounded by a metal chain link fence, with the exception of the wooden gate.

Terrain :

This area is a moderately flat region. The cemetery gate is about 10 m from Shirley Road and slightly uphill from the road. There is a gentle ditch between the road and the cemetery and a very gentle upward slope from Shirley Road, towards the cemetery. The grenade range has similar characteristics.

Vegetation :

At the cemetery and immediately around the cemetery the vegetation cover is grass. Nearby on the south and west sides of the cemetery, are thick tree stands. The north side faces Shirley Road and the Castle Grenade Range. Towards the east, the land is cleared with grass and shrubs growing on it. The Castle is grass covered with patches of bare soil where the organic material has been burnt.

Soil and Surface Cover :

The soil is covered mostly with vegetation, except for bare mineral soil patches within the Castle range area. There are several tombstones of varying shapes and materials at the cemetery.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
East side of cemetery	-	Grass inside the cemetery and opposite Shirley Road. Tree stands surround 2 sides.	201° camera heading	A32	97-1710
West side of cemetery	-	As above	123° camera heading	-	97-1711
West side of cemetery	-	As above	150° camera heading	-	97-1712

Table 29. Ground truthed targets at site 8, the Cemetery and the Castle range. The GPS position is in Table 30. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE AND	UTM – WGS84 DATUM
A32	45° 50′ 16.1″N, 66° 23′ 31.1″W	702533 E, 5079336 N

Table 30. The GPS positions for site 8, the cemetery and Castle Range are given here. See Table 29 and Figure 30.

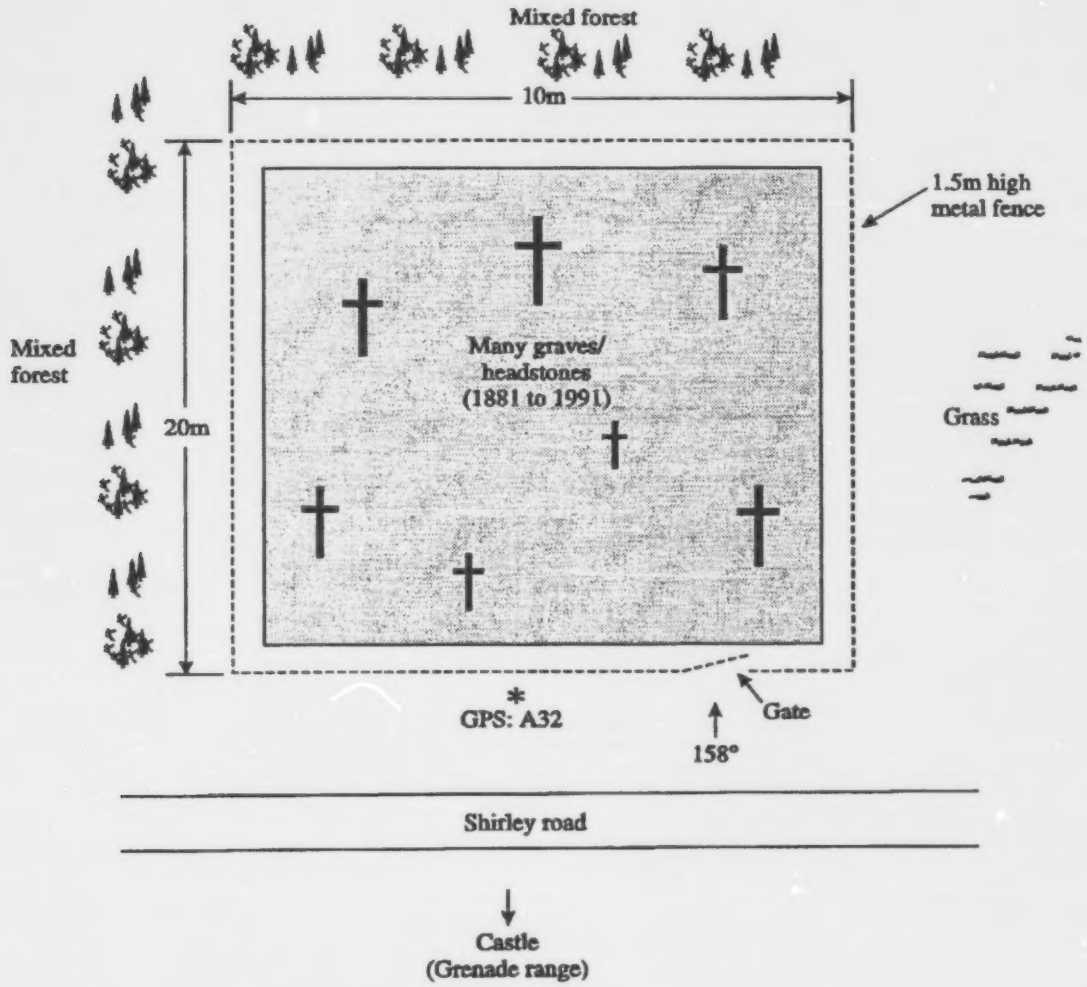


Figure 30 Depiction of the cemetery which is opposite the Castle Range. All dimensions are approximate.

Ground Truth Summary of Site 9: Camp Petersville

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Tables 31, 32):

Camp Petersville (shown in Figures 31 - 33) is a major supply and storage area for camp exercises. Only a small subsection of this center was truthed. In particular, the main structures truthed include the following; 2 large propane tanks, a transformer, several buildings of which many have a metal roof and which are enclosed with a metal chain link fence. These are located on a large gravel and sandy parking lot where the parked traffic is likely transitory. Also in the region is a large tent where vehicles are often kept inside. There are minor power lines and poles, which are erected along Worthington Road, but stop in the middle of the truthed area. When we were there, further poles continued along the road but were not strung with any lines. On the other side of the road, another parking lot, which is the mirror image of this one, is located. Refer to digital air photographs from August 13, 1996 and September 6, 1996 for an aerial view of the site and surrounding area. Note from Figure 31, the geographic positions for the NW, NE, SW and SE corners are denoted respectively as SV1, SV2, SV3 and SV4. These geographic coordinates follow;

- SV1 - 45° 34′ 39.3″ N, 66° 22′ 11.8″ W or E 705195, N 5050481
- SV2 - 45° 34′ 41.2″ N, 66° 22′ 05.1″ W or E 705337, N 5050544
- SV3 - 45° 34′ 36.3″ N, 66° 22′ 09.5″ W or E 705246, N 5050389
- SV4 - 45° 34′ 38.1″ N, 66° 22′ 03.4″ W or E 705337, N 5050451

Terrain :

Camp Petersville is at the top of a large and gently rounded hill, which is downslope from McGuire Hill. It is near a large interchange between Highway 7 and Worthington Road. This interchange was completed in 1996. The truthed region is at the edge of the camp and is a large, flat parking lot. Nearby are at least 2 more large parking lots. From the truthed area, Worthington Road continues further down into the valley, which is heavily forested. Worthington Road is the access route to the truthed area and is a major transport route for the military. This road continues eastward from the intersection, downhill to more interior parts of the base. On the other side of the road from the truthed area is another immense parking lot which is almost a mirror image of this parking lot.

Vegetation :

Surrounding the region, with the exception of the roadside, are shrub and tree stands of mixed species and sizes (ranging from 1 m to 4 m). The forest extends down into the valley for miles. The parking lot, opposite to the truthed area is also surrounded by forested area.

Soil and Surface Cover:

The parking lot is mostly covered with crushed rock and possibly oil. There appears to be 2 distinct types of gravel; one has more of a reddish, sandy appearance that may be

due to the crushed rock origin (may be the red shale at the rock quarry site) while the other gravel appearance looks more conventionally greyish toned. This region appears well drained. There were barrels and other items, which are likely transient objects in the area.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS, GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Parking lot	-	on gravel	59° camera heading	B1	97-1713
Transformer & fire retardant	-	on gravel	16° camera heading	B1	97-1714
Propane tank	-	on concrete next to gravel, surrounding rocks	337° camera heading	B1	97-1715
Propane tank	-	on concrete next to gravel, surrounding rocks	307° camera heading	B1	97-1716
Fenced region	-	on gravel, some small brush	281° camera heading	B1	97-1717
Tent	-	on gravel	209° camera heading	B1	97-1718
Small building & parking lot across the road	-	on gravel	150° camera heading	B1	97-1719
Building within fenced region	-	on gravel, shrubs and grass near fence	199° camera heading	N/A	97-1720
Trailer, truck within fenced region	Truck # 92636, likely transient	as above	120° camera heading	N/A	97-1721
Small building & tent viewed from SW fence corner	-	on gravel	125° camera heading	N/A	97-1722
Small building between bush & fenced area	-	on gravel near brush and fence	358° camera heading	N/A	97-1723
Propane tanks from SE fence corner	-	gravel, tanks on concrete	97° camera heading	N/A	97-1724

Table 31. Ground truthed targets at Camp Petersville. GPS measurements are in Table 32. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE & LONGITUDE	UTM – WGS84 DATUM
B1	45° 34′ 39.18″ N, 66° 22′ 09.72″ W	705240 E, 5050479 N
B2	45° 34′ 38.03″ N, 66° 22′ 11.53″ W	705202 E, 5050441 N

Table 32. The GPS measurements recorded at site 9, Camp Petersville. See Table 31 and Figure 31. The GPS receiver did not work very well at the time of these measurements and it became unfunctional for the remainder of the day.

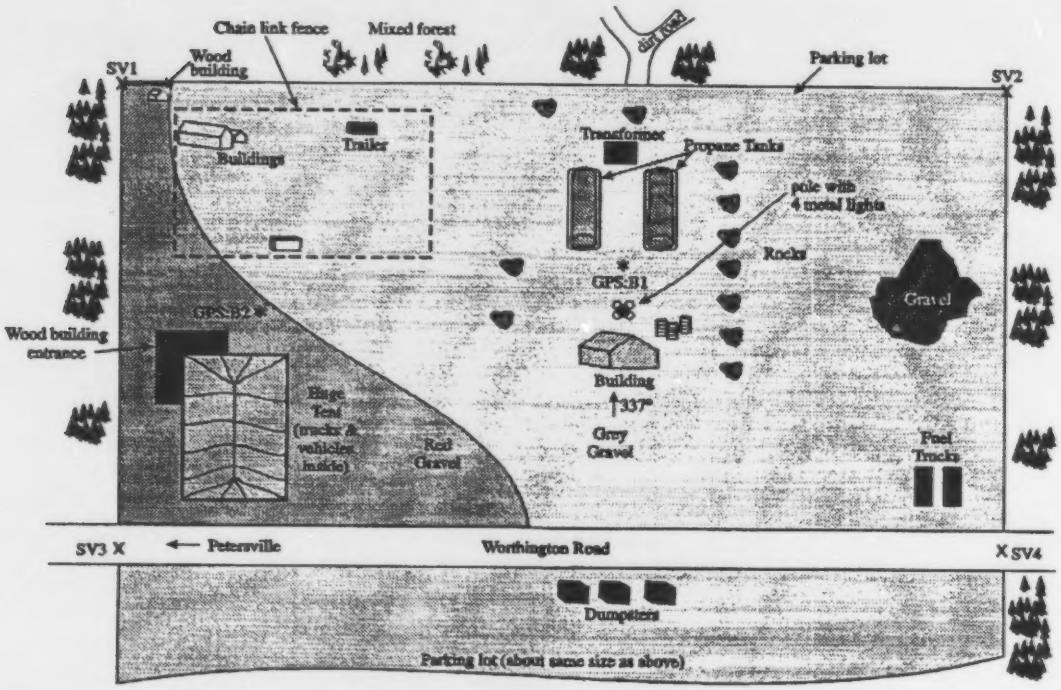


Figure 31. General schematic layout of site 9, Camp Petersville (not to scale). See Figures 32 and 33 for greater detail. GPS information can be found in Tables 31 and 32.

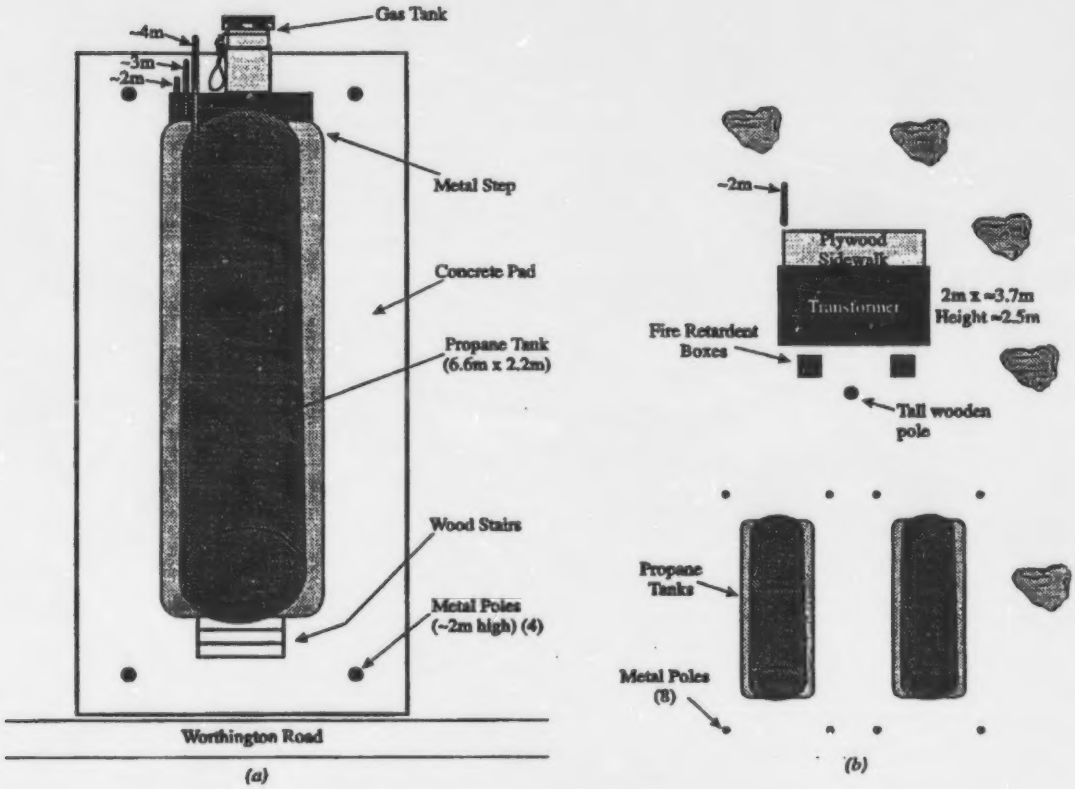


Figure 32. Close-up view of (a) one of the propane tanks (tanks were almost completely identical) and (b) the transformer and the 2 propane tanks at Camp Petersville (not to scale). See referenced photographs in Table 31 for more detailed information.

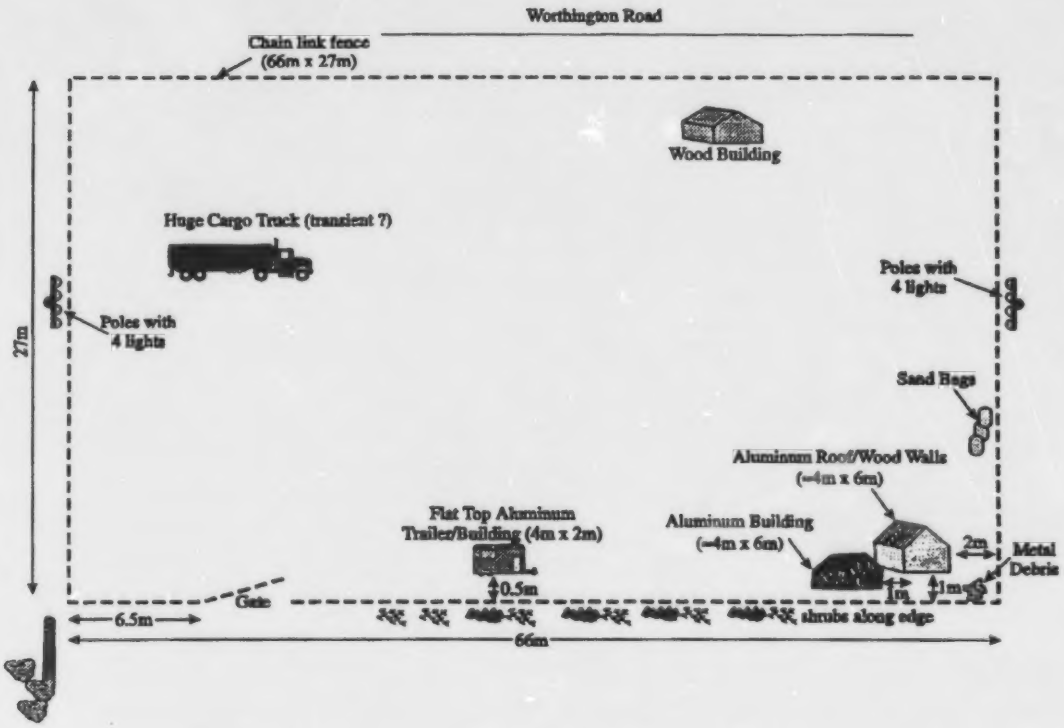


Figure 33. Close up view of fenced area at Camp Petersville (not to scale).

Ground Truth Summary of Site 10: Blissville Airport

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Table 33) :

This unmaintained runway (about 1.2 km long and 45 m wide, shown in Figure 34) is in poor condition. Grass and scrub brush are growing in worn regions of the runway. This runway is no longer completely flat and it shows some evidence of heaving from winter conditions. At each end of the runway and on a small adjoining leg of the runway are large apron extensions. Nearby is a small group of homes with their back yards facing the runway and their front yards facing a road and railway. A small dirt road continues from the edge of the runway into the surrounding forested region as can be seen in Figure 34. Nearby there is a bog (possibly a metal transformer) and a building.

Terrain :

The terrain is very flat and is part of a broad valley where the industry is predominantly farming.

Vegetation :

Grass and small scrub brush surround the runway. The runway is surrounded by forest on all sides with the exception of the side where the homes, road and railway are. The homes are wedged between the airport and a vast, flat farming region within a very broad valley. There is a spruce stand near the north end of the runway.

Soil and Surface Cover :

Judging by the nearby farms, the soil appeared fairly fertile. There was a barrel on the runway.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Runway	N/A	Grass	326° camera heading	-	97-1726
Runway	N/A	Grass	-	-	97-1732
Grass and brush near runway	N/A	Grass	-	-	97-1733
Track near runway end	N/A	Brush	-	-	97-1734
Track in brush	N/A	Brush	-	-	97-1735

Table 33. Ground truthed targets at Blissville Airport. N/A represents not applicable and a dash (-) represents that there is no information.

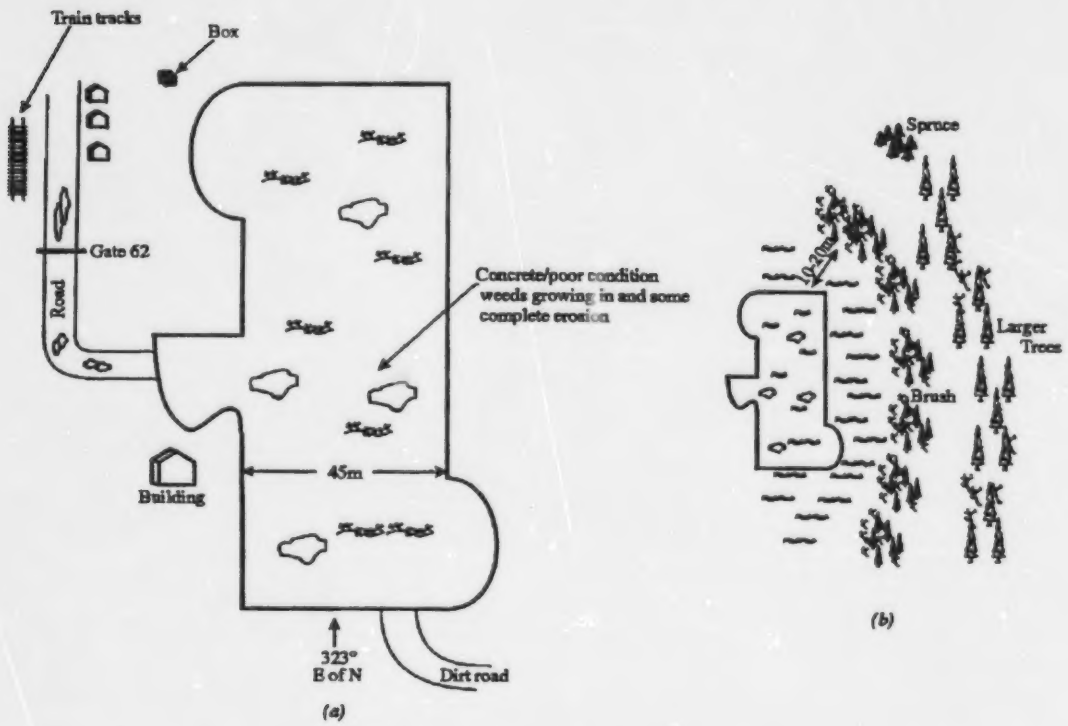


Figure 34. The right hand side (a) shows an overview of the region and its surrounding vegetation while the left hand side (b) emphasizes Blissville airstrip.

Ground Truth Summary of Site 11: Red Pine Stands

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Table 34) :

Natural red pine stands (see Figure 35) were found on both the east (stand a) and west (stand b) sides of Highway 660, which was a paved road with ditches on both sides. These stands were 1.5 km north of gate 68. One stand appeared to be CT while the other stand consisted of predominantly large pines with smaller mixed species in the underbrush. There is a clearing behind stand (a) which had the appearance of a boggy area. A mixed species forest (stand c) consisting predominantly of pine, spruce and birch trees, of varied sizes was found along a trail near gate 68. Stand c had very tall red pines (25 m) with wide trunks (0.8 m diameter). About 1 km downhill on this path, the micro-environment becomes more swampy and clumps of black spruce are found there. Two kilometers north of gate 68 on Highway 660 is another pine stand (stand d) which extends along the roadside for 50 m and is on the east side of the road. At 3.1 km north of gate 68 there is another pine forest stand (stand e) on the west side of the road which extends for 25 m. The pines here are about 15 m high and the forest floor is covered with underbrush and some spruce which are also about 15 m high.

Terrain :

The terrain was very gently sloped to the north. The trail from gate 68, descended down a hill.

Vegetation :

Grass and small scrub brush surround the ditch or trail. There were some very large pine trees (greater than 20 m) in some of the stands. Different types of pine stands were found and included:

(1) pine stand (looked CT) with spruce and deciduous underbrush [stand a, b (pines with 20 cm trunks and densities of 1.5 pines per square meter) and stand d]
(2) mixed forest with very large pine and spruce trees [stand c – pines with trunk sizes of 0.6 m diameter]
(3) forest stands with very large pine trees (greater than 15 m tall) with dense mixed species underbrush including 15 m tall spruce. The tree density is about 1 tree per square meter [stand e].

Soil and Surface Cover :

The forest floor is covered with brush and looks like a sandy clay soil mixture. At the lower portions of the hill where the spruce stand is, it is wet and boggy while at higher elevations, in the pine forest stands, the soil appears well drained.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Pine forest	-	Between 1.5 – 1.65 km N of gate 68, off Hwy 660	N/A	Hwy 660	97-1730
Pine forest	-	as above	N/A	Hwy 660	97-1731
Underbrush on trail extending from gate 68	mixed, small aspen and pine	0.1 km from gate 68 and down a trail	N/A	Path from gate 68	97-1735
as above	As above	as above except about 0.2 km down the trail	N/A	Abov e	97-1736
as above; red pine emphasized	As above	as above; emphasizing sizes & mixed species	N/A	above	97-1737
as above	0.7 km down path	as above except 0.7 km down the path, pine size emphasis relative to smaller hardwoods	N/A	above	97-1738
Pine stand, mixed species	Near roadside	Between 1.5 & 1.65 km N of gate 68; off Hwy 660,	East of Hwy 660	Hwy 660	97-1739
Predominant pine stand, mixed	As above	as above	West of Hwy 660	above	97-1740
Pine stand	As above	as above	East of Hwy 660	above	97-1741
Pine stand	As above	Emphasizing size with standing person	East of Hwy 660	above	97-1741
PCT Pines	Pines & small spruce, shrubs	Between 2. & 2.05 km N of gate 68; off Hwy 660; very little underbrush, pine needle covered soil.	East of Hwy 660	above	-
Predominant pines with large spruce (15 m) & mixed species underbrush	large pines (20m)	Between 3.1 & 3.4 km N of gate 68,	West of Hwy 660	above	-

Table 34. Ground truthing of the pine forests found along Highway 660. Drawing is no to scale. N/A represents not applicable and a dash (-) represents that there is no information.

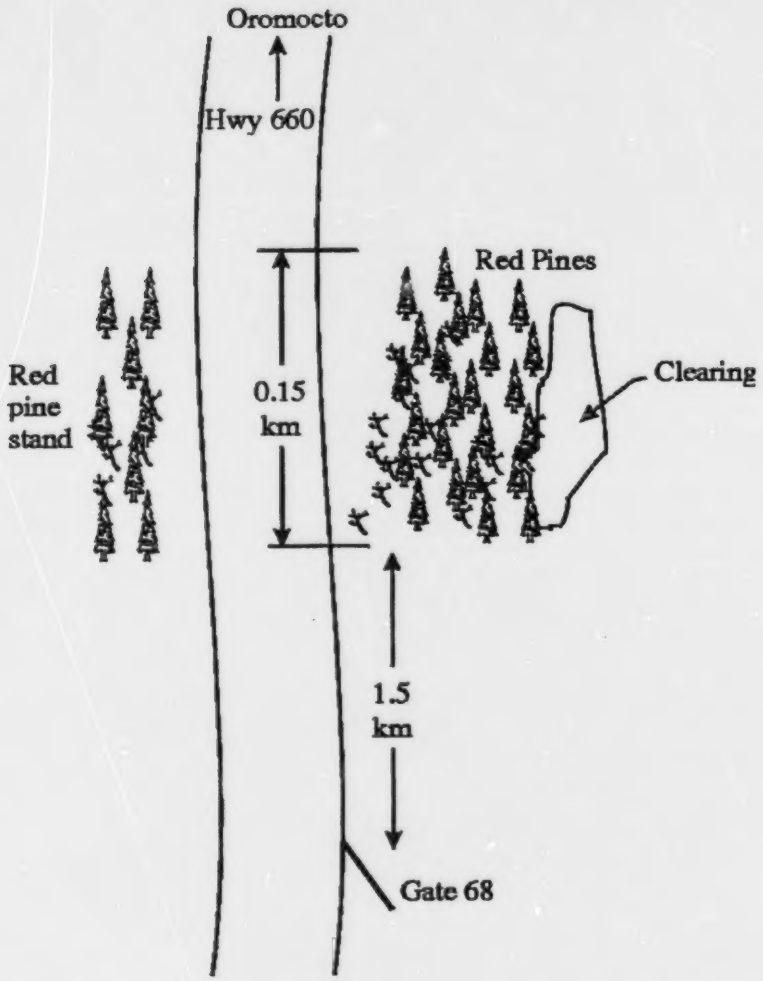


Figure 35 Pictorial representation of pine forest locations directly next to Highway 660. There was a clearing behind the red pine forest (on the right hand side of this figure) which likely was either a wet boggy area or a meadow.

Ground Truth Summary of Site 12: Forest Fire Planes on Tarmac

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Tables 35 and 36):

Six World War II planes (Grumman Avengers, TBM-3) have been converted for use as fire-fighting planes. This area was truthed twice; once from outside the airport fence (Figure 36) and the next time within the fence limits. These old planes (with the exception of perhaps one) have not been moved from the tarmac for the past year because forest fires were scarce during that time. The location of these planes is directly off Highway 102 and next to the Fredericton airport. Nearby, are fuel tanks, large metal roofed buildings, other planes, metal mesh fences and plane parts. The survey marker, SM1 shown in Figure 36, was labelled NB Survey #299. This survey marker was about 10 m from the nearest plane. About 30 m away and along the outer fence was another survey marker, SM2 which was labelled #19 (LS24, 167, (S5), 60, Control Survey Section, Survey and Mapping Div. IRIS, PO Box 1660, Summerside, PEI). A power pole near the highway and by SM2 was labelled; 169, 55, 58.

Terrain :

The terrain was very flat and near the river edge. The fence enclosing the area was directly next to the ditch by Highway 102.

Vegetation :

Grass cover surrounded the tarmac and fenced region. The environment was a typical airport scene with tarmac surfaces, buildings, planes and fuel tanks.

Soil and Surface Cover :

Tarmac and gravel was the primary surface at the airport. The soil drainage appeared to be fairly good in the region.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING (E OF N)	GPS OR REF PNT	PHOTO ID #
fire planes on tarmac	-	View from fence, planes on tarmac, near metal building	282°camera heading	Power pole	97-1807
Planes	-	View from fence, near fire planes, on tarmac	257°camera heading	Power pole	97-1808
Vehicles and metal building	-	View from fence, near fire planes and Hwy 102	305°camera heading	Power pole	97-1809
Metal building	-	West of fire planes on tarmac	178°camera heading	Power pole	97-1810
fire planes	-	View from Hwy 102, near grass, vehicles & oil tanks	-	near survey SM1	97-1811
oil tanks, vehicles & metal building	-	View west of planes	286°camera heading	Survey SM1	97-1812
fire plane	Front wing view	-	165°camera heading	C2	97-1834
Fire plane	Front view	-	127°camera heading	near C2	97-1837
Plane in parts	-	On gravel, near grass & tarmac	163°camera heading	C1	97-1838
Plane in parts	-	On gravel, near grass & tarmac	229°camera heading	-	97-1839
fire planes in row	Tail view	On tarmac, near gravel	20° camera heading	-	97-1840
fire planes in row	Tail view	On tarmac, near gravel	237°camera heading	-	97-1842
fire planes	Rear view	-	-	-	97-1843

Table 35. Ground truthed forest fire planes on the tarmac at the Fredericton Airport. GPS measurements are in Table 36. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE & LONGITUDE	UTM – WGS84 DATUM
C1	45° 52′ 36.17″ N, 66° 32′ 14.18″W	691116 E, 5083300 N
C2	45° 52′ 37.28″ N, 66° 32′ 13.01″W	691140 E, 5083335 N

Table 36. GPS positions for site 12, the forest fire fighting planes at Fredericton Airport. See Table 35 and Figure 36.

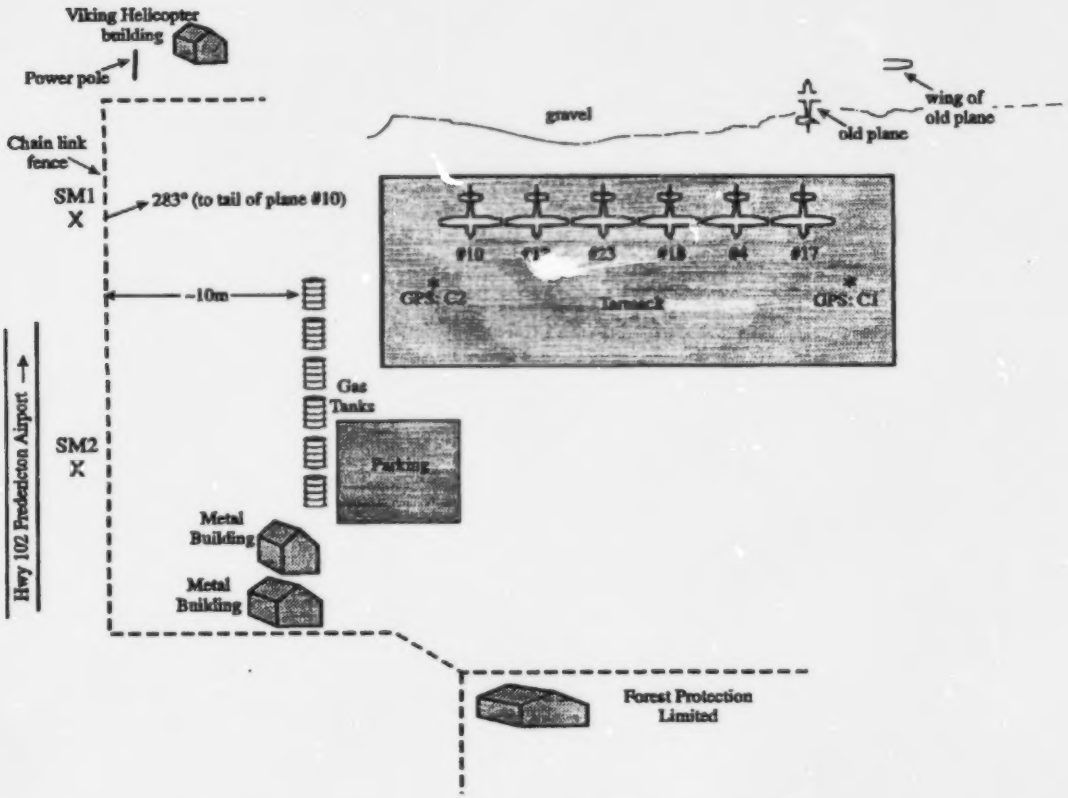


Figure 36 Representation of the forest fire planes on the tarmac near the Fredericton airport. This is only a schematic drawing which does not show the planes' wings as they were, in a folded state. The planes are shown in the photographs and referenced in Table 35. In their folded configuration, the planes had approximate length and width dimensions of 6.5 m and 4 m in respective order. Average separation between the planes was about 1 m.

Ground Truth Summary of Site 13: Display Military Vehicles

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Tables 37 and 38):

The following display vehicles truthed include; a Sherman tank, a Bren Gun Carrier and a Howitzer (M114). They were all displayed on concrete slabs. They were near the base entrance in Oromocto on Tilley Road which connects with Broad Road. A parking lot (which was filled with other transient targets) was situated near these targets.

Terrain :

The terrain was an urban landscape and was very flat.

Vegetation :

Grass cover was the vegetation near these targets in this urban area.

Soil :

Concrete was directly below the display vehicles and was surrounded by grass. This was a relatively clean, urban environment with minimal litter.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Sherman Tank	Markings: M4A2 E8 HV55	On concrete slab; 8.45 m x 3.91 m	-	C3	-
Bren Gun Carrier	-	On concrete slab; 3.55 m x 1.97 m	-	C4	-
Howitzer	M114	On concrete slab; 8.44 m x 3.92 m	-	C5	-

Table 37. Ground truthed display vehicles at CFB Gagetown's Headquarters. GPS measurements are in Table 38. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE & LONGITUDE	UTM – WGS84 DATUM
C3	45° 50′ 25.18″ N, 66° 28′ 09.99″W	696508 E, 5079422 N
C4	45° 50′ 22.85″ N, 66° 28′ 08.42″W	696545 E, 5079352 N
C5	45° 50′ 22.59″ N, 66° 28′ 08.45″W	696543 E, 5079343 N

Table 38. The GPS measurements for site 13, the display military vehicles. See Table 37.

Ground Truth Summary of Site 14: Sand and Gravel Pits

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Tables 39 and 40):

The sand and gravel pits were immediately off of Highway 102 and consisted of three distinct pits which are positioned sequentially away from the highway (See Figure 38). Adjoining all of them is a gravel road, which extends perpendicularly from the highway. The sand and gravel had a reddish hue, which could indicate a high iron content. The gravel road continued from the pits and through a forest. There is a house directly between Highway 102 and the pit nearest to the road. Work-related vehicles (grater, truck) were parked in the pit nearest the highway when the area was truthed.

Terrain :

The terrain was a flat flood plain near the river.

Vegetation :

Grass was alongside the disturbed excavated region. At the southern edges of the site, there was evidence of the 1986 forest fire, in the form of many large charred trees amongst the regenerated forest stand. The regenerated mixed forest was populated with varying heights and species types.

Soil :

The soil looked like a glacial deposit of sand and gravel, with strewn large boulders and rocks.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Gravel pit, metal bldg, toilets	-	Many small boulders and glacial debris littered here also	306°	C6	-
Metal bldg, toilets, trailer	-	Sand and Gravel surface	282°	C6	-
Pine tree stand, vehicle,	-	Tall pines (15 m) along the road	114°	C6	-
River in distance	-	N/A	23°	C6	-
Regenerated forest after forest fire	-	Large burnt stumps amidst mixed forest of mixed sizes	-	C7	97-1916, 97-1917
2nd pit	From end of 1st pit furthest from hwy	Surrounded by brush of mixed sizes and no greater than 2m high	-	C7	97-1918
1st pit	As above	As above	-	C7	97-1919

Table 39. Ground truthed sand and gravel pit. GPS measurements are in Table 40. See Figure 37 for a depiction of the pit locations. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE AND LONGITUDE	UTM – WGS84 DATUM
C6	45° 50′ 05.18″ N, 66° 13′ 16.81″W	715796 E, 5079445 N
C7	45° 50′ 01.66″ N, 66° 13′ 21.64″W	715696 E, 5079334 N

Table 40. GPS measurements for Site 14, the gravel and sand pits. See Table 39 and Figure 37.

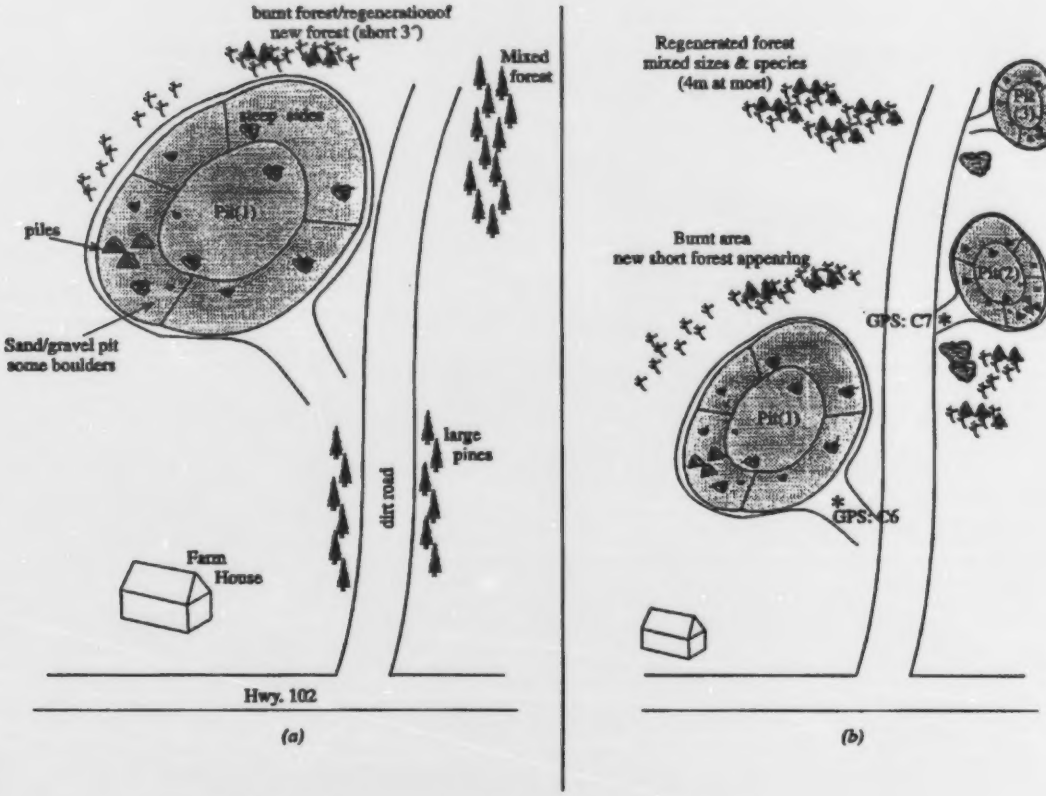


Figure 37 The right hand side (b), shows the location of the gravel/sand pits relative to each other while the left hand side (a), emphasizes the pit nearest to Highway 102.

Ground Truth Summary of Site 15: December 11, 1996 Ground Truth Site

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Tables 41 and 42):

We visited the site which was ground truthed by CFB Gagetown personnel on December 11, 1996 while a Radarsat image captured a battle exercise there. The exercise took place on a broad hill, which was forested further down in the valley. We acquired more information of the area and the approximate heading of the vehicles and guns that were captured in the image. A wrecked, burned vehicle separated into at least 3 pieces was ground truthed there also.

Terrain :

The exercise was conducted on a slope of a broad hill. From the hilltop, the surrounding valley could be viewed.

Vegetation :

The hilltop is mostly devoid of vegetation from the military vehicle traffic. There is some remaining small brush and grass near the top of the hill. Further down from where the guns were placed in the exercise, the vegetation is mostly mixed small brush about 1.5 m high. A mixed forest is below this brush and extends throughout the valley. In the area where the wrecked vehicle was, one finds grass and scrub brush with tree stands in close proximity.

Soil :

The soil was a sandy clay base with some gravel. The region has strewn metallic and glass garbage on the ground. There were also culverts, a wooden box and poles on the ground.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Approx. gun positions Dec 11/96	Howitzer 105 guns	Bare tracked soil, some grass and shrubs nearby	133° / 184° camera heading	D5	Digital 7/8
wreck & environment	-	From hilltop, general environment	-	near D5	97-1924
uphill trail from wreck	-	General environment uphill from wreck	-	D6	97-1925
wreck piece 1	8 ft long	Bare soil, some brush & grass, mixed tree stands begin about 10 m from wreck	98° camera heading	D6	97-1926
wreck piece 2	12 ft long	as above,	63° camera heading	D6	97-1927
wreck piece 2	As above	as above	69° camera heading	D6	97-1928
uphill from wreck	-	as above	277° camera heading	D6	97-1929
wreck piece 2	-	as above	137° camera heading	D6	97-1930
Hilltop view	-	Bare soil, some grass	158° camera heading	-	97-1931
view from hilltop to Lawfield Road	-	as above	108° camera heading	-	97-1932
wreck	12 ft part	as above	351° camera heading	D6	digital 9

Table 41. Ground truthed environmental data at the December 11, 1996 site. GPS measurements are in Table 42. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE & LONGITUDE	UTM – WGS84 DATUM
D5	45° 42′ 27.05″ N, 66° 14′ 42.63″W	714432 E, 5065244 N
D6	45° 42′ 31.58″ N, 66° 14′ 34.62″W	714600 E, 5065389 N

Table 42. GPS positions at December 11, 1996 battle exercise site.

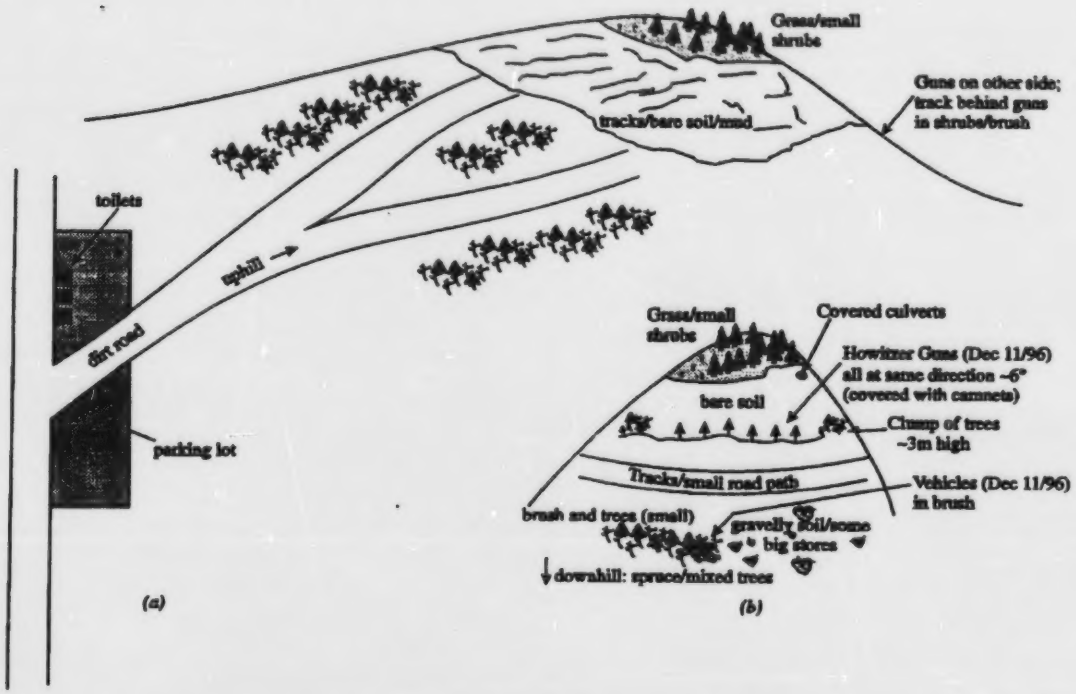


Figure 38 The upper picture, (a) depicts the overall site geometry while the lower picture, (b) depicts the location of the guns and trucks (Dec 11/96) on the other side of the hill relative to what was shown in the top picture.

Ground Truth Summary of Site 16: Transformer at Oromocto

Infrastructures, Targets, Buildings and Distinct Environmental Features (see Tables 43 and 44):

This was a large transformer in the townsite of Oromocto. It is on the north side of McDonald Road at the western edge of the Oromocto Indian Nation Reservation which is near the St. John riverside. We truthed it from outside of the metal mesh fence (27 x 30 m). The transformer was very large with several appendages which would make good corner reflectors. Houses were located within 50 to 75 m of the transformer.

Terrain :

The transformer was inside of a gentle gully. The houses nearby, were uphill from the transformer.

Vegetation :

The nearby vegetation is mostly small brush and grass.

Soil :

The soil is predominantly organic, black earth.

TARGET OR FEATURE	TARGET DETAILS	ENVIRONMENTAL DETAILS , GENERAL INFORMATION	HEADING OR BEARING	GPS OR REF PNT	PHOTO ID #
Transformer in Oromocto	N/A	Gravel surface within fenced area, concrete block directly below transformer	348° camera heading	D7	97-1936
Transformer	N/A	as above	348° camera heading	D7	97-1937
Transformer	N/A	as above	260° camera heading	East side of fence	97-1938

Table 43. Ground truthed information of the transformer at Oromocto. GPS measurement is in Table 44. N/A represents not applicable and a dash (-) represents that there is no information.

GPS #	LATITUDE AND LONGITUDE	UTM – WGS84 DATUM
D7	45° 51′ 07.59″ N, 66° 27′ 59.02″W	696704 E, 5080738 N

Table 44. GPS position at the transformer station at Oromocto.

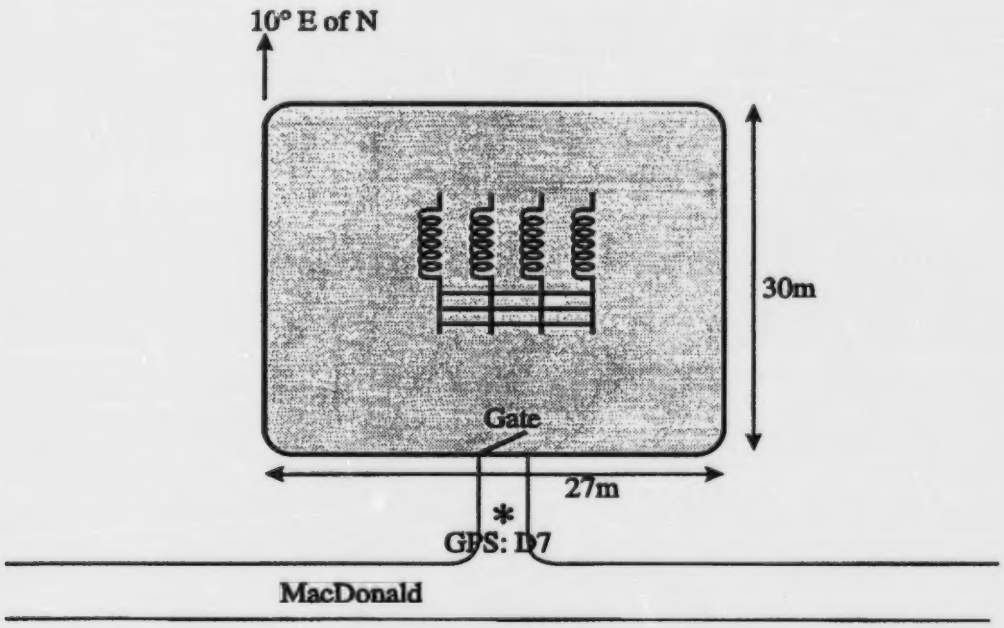


Figure 39 A schematic representation of the transformer in Oromocto.

APPENDIX D PHOTOGRAPHS

This appendix is divided into three parts. The first and second parts (D1 and D2) briefly document the photographs taken respectively from the air and from land. The third part (D3) contains all the photographs with the digital photographs preceding the film photographs.

A collection of geo-referenced air photographs over CFB Gagetown is included and should be a helpful reference for acquiring information about the environment and infrastructures in the area.

The digital photographs in Section D3 are arranged sequentially by day and the photograph number for that day. The film photographs are displayed in sequential order of the DREO photograph number. The format of the DREO photograph number is the last two digits of the year that the photograph was developed, followed by a number (e.g.; 97-01).

D.1 AIR PHOTOGRAPH DOCUMENTATION

Below is a documented list of all the air photographs supplied for this report, in historical order. First the digital photographs are listed and then the film photographs are listed. Following these ground truthed photographs are geo-referenced air photographs of areas on the base which may be of interest.

May 9, 1996: [Kodak Digital Camera]

Photograph Reference #	Description of Photograph
9/May/96-1	South Parade Square, Building J7, CFB Gagetown
9/May/96-2	Heliport, Building L4, CFB Gagetown
9/May/96-3	Heliport, Building L4, CFB Gagetown
9/May/96-4	Firing Point 5
9/May/96-5	Shirley Road, Region 2, dump
9/May/96-6	Shirley Road, Region 2, dump
9/May/96-7	Hersey Bivouc
9/May/96-8	Hersey Bivouc
9/May/96-9	Hersey Bivouc
9/May/96-10	Hersey Bivouc
9/May/96-11	Hersey Bivouc
9/May/96-12	Hibernia Bivouc, Region 25
9/May/96-13	Hibernia Bivouc, Region 25
9/May/96-14	Hibernia Bivouc, Region 25

9/May/96-15	Hibernia Bivouc, Region 25
9/May/96-16	Hibernia Bivouc, Region 25
9/May/96-17	Lawfield Bivouc, Region 37
9/May/96-18	GMA, Lawfield Road
9/May/96-19	GMA, Lawfield Road
9/May/96-20	Worthington Tank Park
9/May/96-21	Worthington Tank Park
9/May/96-22	Worthington Tank Park (Leopard Tanks- sprung shelter)
9/May/96-23	Worthington Tank Park (Leopard Tanks- sprung shelter)
9/May/96-24	Worthington Tank Park (Leopard Tanks- sprung shelter)
9/May/96-25	Cootes Bivouc, Region 42
9/May/96-26	Mobile Bath Unit, Region 35
9/May/96-27	Mobile Bath Unit, Region 35
9/May/96-28	Camp Petersville
9/May/96-29	Camp Petersville
9/May/96-30	Hogans Bivouc, Region 54
9/May/96-30	Hogans Bivouc, Region 54

July 31, 1996: [Kodak Digital Camera]

Photograph Reference #	**Description of Photograph**
31/Jul/96-1	Petersville Camp & Interchange
31/Jul/96-2	Petersville Camp & Interchange
31/Jul/96-3	Petersville Camp Track Parking Area
31/Jul/96-4	Petersville Camp & Interchange
31/Jul/96-5	Petersville Camp & Interchange & Track Parking Area
31/Jul/96-6	Petersville Camp & Interchange & Track Parking Area
31/Jul/96-7	Petersville Camp & Interchange & Track Parking Area (borrow pit NW of Interchange)
31/Jul/96-8	Borrow pit for Interchange
31/Jul/96-9	Track Parking Area (E heading)
31/Jul/96-10	Mabey Bridge (S heading)
31/Jul/96-11	Worthington Tank Park (SW heading)
31/Jul/96-12	Worthington Tank Park (NW heading)
31/Jul/96-13	Intersection of Lawfield, Murphy and Invicta, (N heading)
31/Jul/96-14	Intersection of Worthington and Clones, (NW heading)
31/Jul/96-15	Interchange at Petersville (W heading)
31/Jul/96-16	Interchange at Petersville (NW heading)
31/Jul/96-17	S of Interchange at Petersville (N heading)
31/Jul/96-18	Interchange at Petersville (NE heading)
31/Jul/96-19	N of Interchange at Petersville (E heading)
31/Jul/96-20	Interchange at Petersville
31/Jul/96-21	Interchange at Petersville
31/Jul/96-22	Interchange at Petersville (SW heading)
31/Jul/96-23	Interchange at Petersville (W heading)
31/Jul/96-24	Interchange at Petersville (NW heading)

31/Jul/96-25	Interchange at Petersville (NW heading)
31/Jul/96-26	Interchange at Petersville (NE heading)
31/Jul/96-27	Interchange at Petersville (NE heading)
31/Jul/96-28	Crashed Plane (W heading), Enniskillen region
31/Jul/96-29	Crashed Plane (NW heading), Enniskillen region
31/Jul/96-30	Crashed Plane, Enniskillen region
31/Jul/96-31	Enniskillen region
31/Jul/96-32	Camp Petersville Parking (S heading), distant mountains
31/Jul/96-33	Bell Bridge, MLBU Site (SW heading)
31/Jul/96-34	Merrit Bridge, ACCRO (new) Bridge (NW heading)
31/Jul/96-35	Lyons Bridge (W heading)
31/Jul/96-36	Old Farmhouse (W heading)
31/Jul/96-37	Fowlers Ford and Rapids (NW heading)
31/Jul/96-38	Old Farmhouse (NW heading)
31/Jul/96-39	Old Farmhouse (NE heading)
31/Jul/96-40	Mount Champlain towers
31/Jul/96-41	Mount Champlain towers
31/Jul/96-42	Mount Champlain towers
31/Jul/96-43	Mount Champlain towers
31/Jul/96-44	Mount Champlain towers
31/Jul/96-45	Olinville Bivouc (NE heading)

August 13, 1996: [Kodak Digital Camera]

Photograph Reference #	**Description of Photograph**
13/Aug/96-21	Worthington Tank Park
13/Aug/96-22	Manor Bivouac MLVW on road, MLVW in trees (30 Service Battilion - 2 tent sections, kitchen in trees)
13/Aug/96-23	Bell Bivouc - gravel pad
13/Aug/96-24	Hearst Bivouc, 4ESR, bridge, 10 T HLVW load bed, palette
13/Aug/96-25	Hearst Bivouc, above & tents, stores, dump box, front end loader, 10 ton Terex dump truck, MLVW
13/Aug/96-26	Hearst Bivouc, 4ESR, tents (4), 5 ton MLVW and trailer
13/Aug/96-27	Hearst Bivouc, 4ESR, 5 ton bridging truck in trees
13/Aug/96-28	Olinville Bivouc, 2 MLVWs, 2 jeeps (Atlantic Brigade Reg)
13/Aug/96-29	Camp Petersville Interchange construction, (base camp school)
13/Aug/96-30	Camp Petersville Interchange
13/Aug/96-31	Camp Petersville
13/Aug/96-38	Camp Petersville, 2- 2.5Ton MLVW, 1 jeep, garbage bin, 2 cylindrical propane tanks
13/Aug/96-41	Hearst Bivouc, see image 5
13/Aug/96-42	Hearst Bivouc, 4ESR, POL vehicle, tents,
13/Aug/96-43	Hearst Bivouc, 4ESR, engineering vehicle, jeep
13/Aug/96-44	Hearst Bivouc, 4ESR, 5 ton bridging truck
13/Aug/96-45	Fowler's Ford on Nerepis River, 4ESR,

engineer's bridge site, tents and trailor

August 16, 1996: [Kodak Digital Camera]

No documentation was provided by the personnel at CFB Gagetown, for the photographs on this day. They are included since they may be useful as a reference. Some observations follow; photograph 4, 9 and 35 show the berm at Site 1 while photographs 5 and 33 show the ravine area at Site 1.

September 6, 1996: [Kodak Digital Camera]

Photograph Reference #	**Description of Photograph**
6/Sep/96-22	St John River
6/Sep/96-24	Firing point 6 - concrete pad (larger white dots)
6/Sep/96-25	Firing point 6 - concrete targets to right of helicopters
6/Sep/96-26	Firing point 6 - helicopter targets (along road, small white dots)
6/Sep/96-27	Firing point 6 - camouflaged helicopter
6/Sep/96-34	Firing points 4 and 5
6/Sep/96-35	Camp Petersville

October 2, 1997: [Kodak Digital Camera]

Photograph Reference #	**Description of Photograph**
2/Oct/97-1 (to -3)	Small Arms Range, small fire scar there
2/Oct/97-4	Route 7 below Small Arms Range, cut '96, cut '91
2/Oct/97-5 (to -6)	Parachute drop zone, will be grubbed soon
2/Oct/97-7	Clear-cut
2/Oct/97-8 (to -11)	Break in clear-cut near river

October 2, 1997: [35mm camera 200ASA film]

Photograph Reference #	Description of Photograph
97-1773	forested area cut in 1990/91 [in 63, near Hwy 660]
97-1774 to 97-1780	clear-cut regions [between 63 & 61]
97-1781	trees left along Mersereau Stream black spruce next to deciduous stand by Mersereau Stream
97-1782	more clear-cuts between Mersereau Stream and Image Brook
97-1783	Image Brook, notice distant mountains
97-1784	clear cut in Mersereau / Irving stream area
97-1785 to 97-1787	black spruce by Irving Brook (see Region 32, 20)
97-1788	Mersereau Stream in distance/ Irving Brook in forefront
97-1790 to 97-1791	Clear-cut areas in Company Attachment in Region 58
97-1793 to 97-1794	Crashed Airplane in Region 57 / Enniskillen
97-1795	Deforested area
97-1796	Intersection of Hwy 7 and Enniskillen Road (I think)
97-1797	Meteorogical Station # 3
97-1798	recent clear cut
97-1799 to 97-1800	marshy area - white pine stand [region 53]
97-1801	Nerepis River [between Regions 44, 45 & 49]
97-1802	Mountain Stream
97-1803	Building and bridge by creek and road (between region 44, 49)
97-1804 to 97-1805	Morgan Lake (bottom of Region 47)
97-1806	near St John River, by Break Neck Hill (Hamilton Wood)
97-1845	George Lake (river, spruce & fir forest nearby)
97-1846	clear cuts by George Lake
97-1847	near Springbok, between Regions 36 & 41, clearcut of old farms
97-1848	gravel benches
97-1849, 97-1850	Murphy Shale pit (Area 36, Hampstead Rd)
97-1851	cemetary
97-1852	Worthington (near Region 30)
97-1853	clear cut by Murphy's pit
97-1854	spruce stand by clearcut near Worthington
97-1855, 97-1856	clearcut area
97-1857	clearcut by Scotty dog woods (note rock piles)
97-1858	close-up of rock piles made by former farm owners
97-1859 to 97-1862	Rathburn Brook in Region 27 (note culverts under road)
97-1863	approaching Long Island on St John R (note: mowed waves in marsh)
97-1864	close-up of Ducks Unlimited "waves" in marsh, level ditching
97-1865	St John R near bottom of Long Island

97-1866 to 97-1875	Long Island on St John R (note: Ducks Unlimited "duck")
97-1876 to 97-1879	Islands on St John River (MusQuash, Long)
97-1880	Isthmus by Otnabog Lake
97-1882 to 97-1883	Clear-cut area, maple leaf emblem, Area 10
97-1884 to 97-1885	Commercially thinned (CT) deciduous forest is parallel to Gamble Rd and extends for about 300 m on both sides of Gamble Rd. Gamble Rd is perpendicular and due east of Lawfield Rd near maple leaf (clear cut in Area 10)
97-1886	Farm near St John R
97-1887	Marsh by Scovil Point, north of Upper Musquash Island
97-1888 to 97-1890	Gagetown Island, town site opposite
97-1891 to 97-1895	St John River and Islands
97-1896, 97-1897	Sand / Gravel Pits
97-1898	St John River & Grand Lake Meadows
97-1899	Sand / Gravel Pit (note: Burned Forest)
97-1900	St John River, Grand Lake Meadows in distance
97-1901	Highway 102, railway
97-1902	near Swan Lake creek
97-1903 to 97-1910	St John River, Islands
97-1911 to 97-1912	Bridges to Oromocto
97-1913 to 97-1914	St John R, Thatch (left) and Oromocto (right) Islands.
97-1915	sand & gravel pit off of Hwy 10

Geo-referenced air photographs

Photograph Reference #	Description of Photograph
97-2488	Knowlton Hill, radio tower, cemetery, PCT forest
97-2489	Heath, spruce and pine forest, note 30 m fire break at area edge
97-2490	Rockwell Demolition site, 30 m fire break
97-2491	Airstrip 1, Shirley Road
97-2492	Argus Company Defensive Position, note berm, ravine
97-2493	Airstrip 2, Hersey Op
97-2494	Hwy 7, commercially thinned forest
97-2495	Enniskillen Area and Road
97-2496	Airstrip 1, Austere Village
97-2497	Murphy Shale Pit, Hampstead Rd, Area 42
97-2498	Fire scar region south of Langemark Small Arms Range
97-2499	below La rvina Wood, regenerated forest after 1986 fire
97-2500	Enniskillen Area, crashed plane, clear cuts
97-2501	Worthington tank park, Hamptstead Rd, Murphy Shale Pit
97-2502	Area 9 & 10, Meteorology Stn 4, Lawfield Bivouac,
97-2503	Meteorology station 7, red pine stand, Branch Rd
97-2504	Area 11, location of Dec 11, 1996 ground truthing

97-2505	Quarry on Morrison Rd (since 1990) in Area 43
97-2506	Quarry off of Drummond Rd
97-2507	Quarry off of Drummond Rd
97-2508	Blissville Airstrip, town & Bivouac, Oromocto R, Hwy 101, 660
97-2509	Firing Pts off Shirley Rd (bright reflections)
97-2510	Gagetown, Gagetown Is, Scoville Pt, Upper MusQuash

D.2 LAND PHOTOGRAPHS

All the photographs taken from land are listed below. The order here is the same as in Appendix D.1, where the digital photographs precede the film photographs.

May 9, 1996: [Kodak Digital Camera]

Photograph Reference #	Description of Photograph
9/May/96-1A to 9A	See May 9, 1996 Ground Truth in Appendix A

May 16, 1996: [Kodak Digital Camera]

Photograph Reference #	Description of Photograph
16/May/96-1 to 11	See May 16, 1996 Ground Truth in Appendix A

December 11, 1996: [Kodak Digital Camera]

Photograph Reference #	Description of Photograph
11/December/96-2 to 19	See Dec/11, 1996 Ground Truth in Appendix A

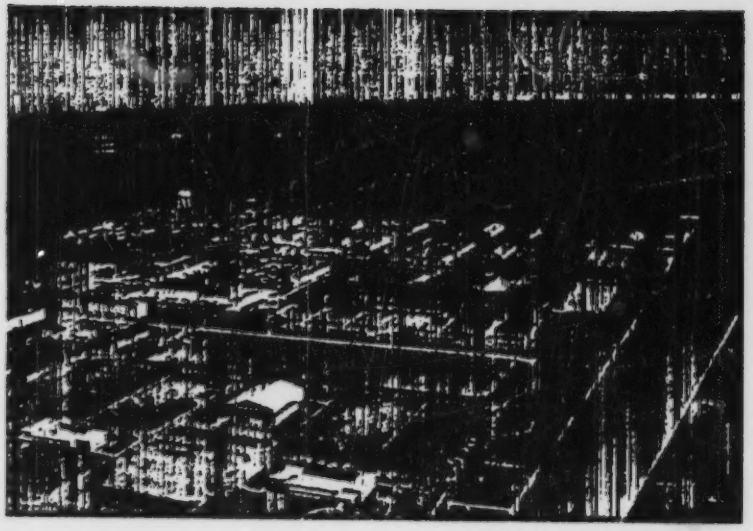
DREO Photographs: [35 mm camera, 200 ASA Colour Film]

Photograph Reference #	Description of Photograph
97-1732	Blissville airport
97-1733	Blissville airport, grass and brush by road

97-1734	end of Blissville runway by dirt road
97-1735 to 97-1736	Red Pines at site 11
97-1737 to 97-1738	path from gate 68, person next to red pines and mixed forest
97-1739	east side of Hwy 660 at site 11/ Red pine forest
97-1740	west side of Hwy 660 at site 11/ Red pine forest
97-1741	east side of Hwy 660 at site 11/ Red pine forest
97-1742	as above, note person next to trees, used for scale
97-1807 to 97-1809	fire planes on tarmac
97-1810	Viking Helicopter next to fire planes
97-1811	view of fire planes
97-1812	oil tanks parallel to road and near fire planes
97-1834	fireplanes, wing view
97-1837	sideview between fireplanes
97-1838 to 97-1839	plane parts
97-1840 to 97-1842	fireplanes in row
97-1843	rear view of fireplane
97-1916 to 97-1917	burnt and regenerated forest
97-1918	middle sand pit
97-1919	back view of the sand pit nearest to the highway
97-1920 to 97-1925	exercise area near Lawfield Road (Nimble Barbara)
97-1926	wreck at Dec 11/96 site
97-1927 to 97-1928	3.5 m piece of wreck (Dec 11/96)
97-1929	view uphill from wreck (Dec 11/96)
97-1930	wreck and background vegetation (Dec 11/96)
97-1931	hilltop view at 158° (Dec 11/96)
97-1932	vegetation from hill towards Lawfield Extension (Dec 11/96)
97-1933 to 97-1935	view from Gagetown marina (S, E, N respectively)
97-1936 to 97-1938	Oromocto transformer respective views (348°, 348°and 258°)

D.3 PHOTOGRAPHS

The following photographs are documented in D.1 and D.2. The digital photographs are placed before the film photographs and are arranged in sequential order by day and number. The film photographs are arranged in sequential order of the DREO number which is printed below the photograph.



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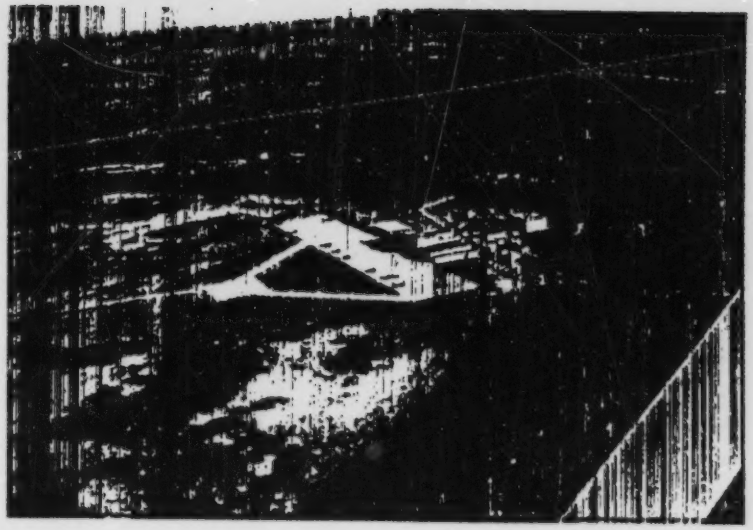

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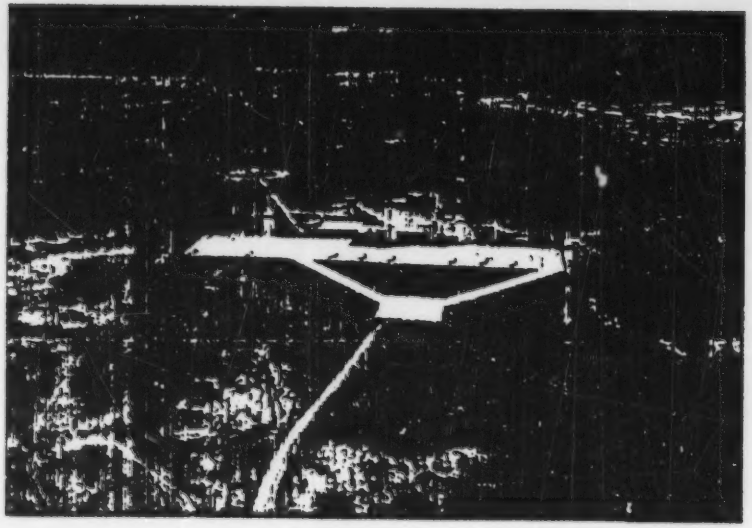

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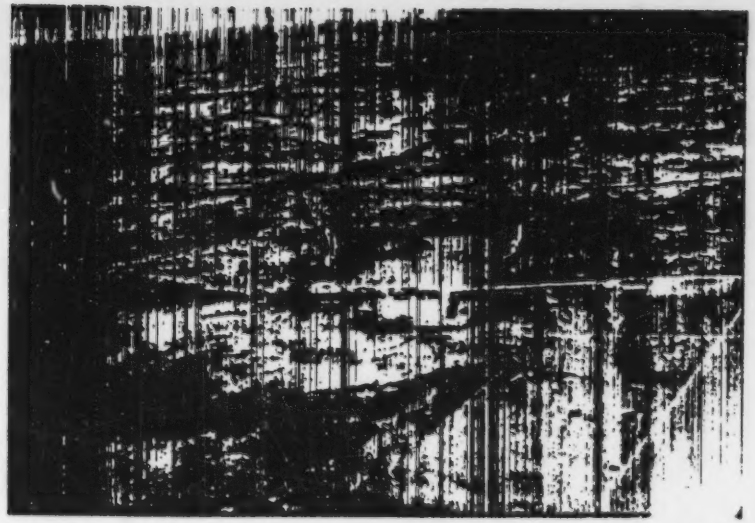

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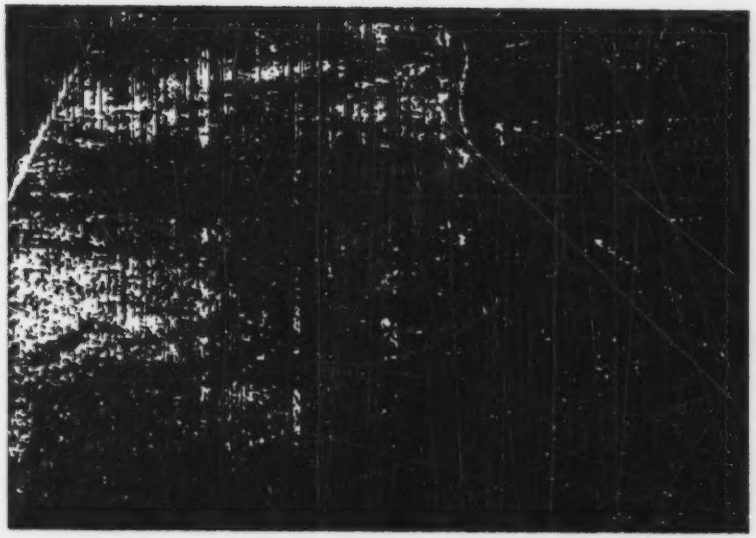

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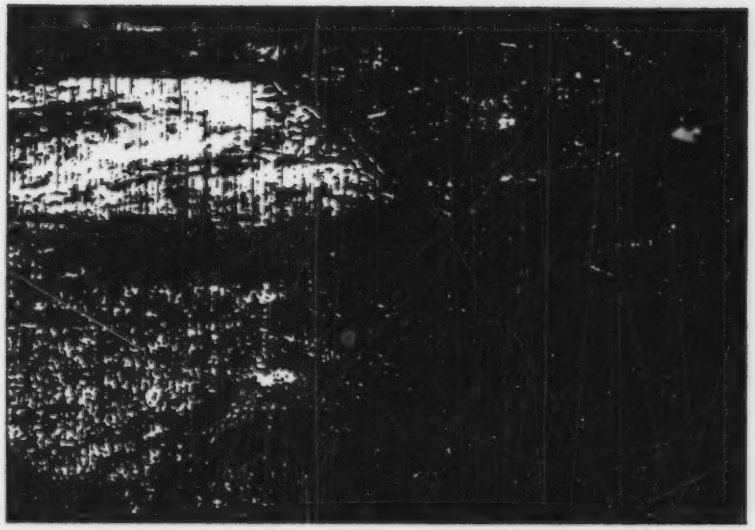

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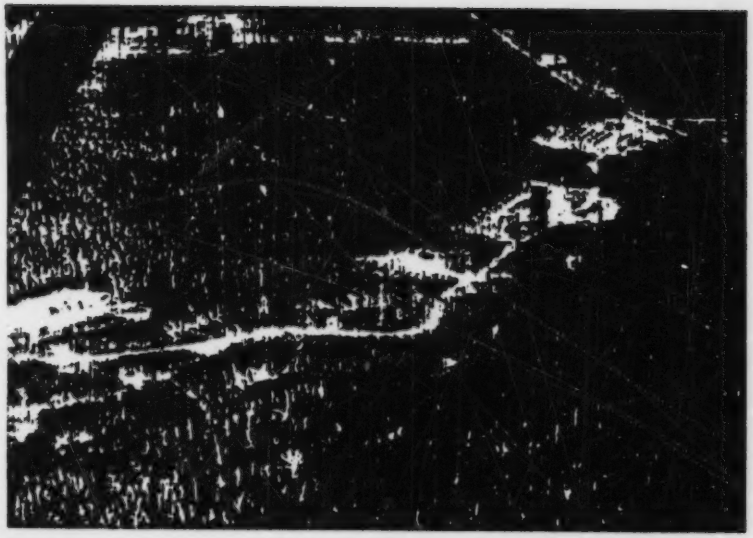

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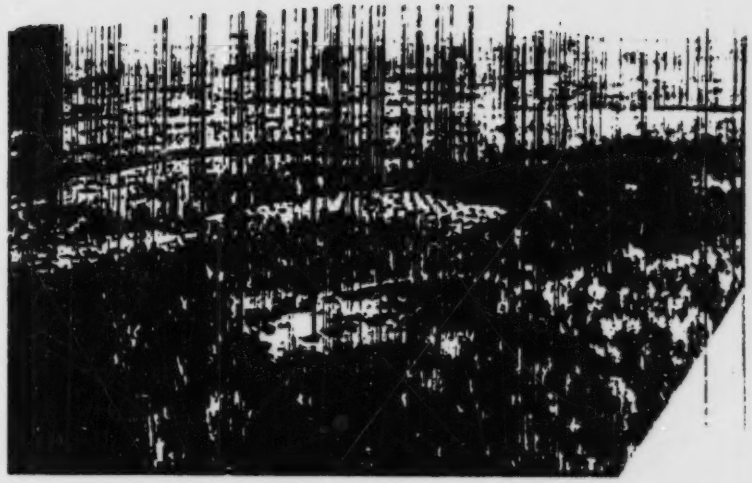

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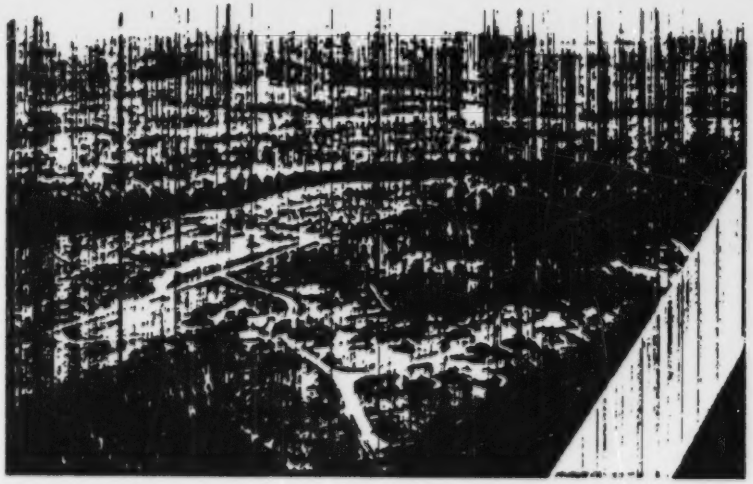

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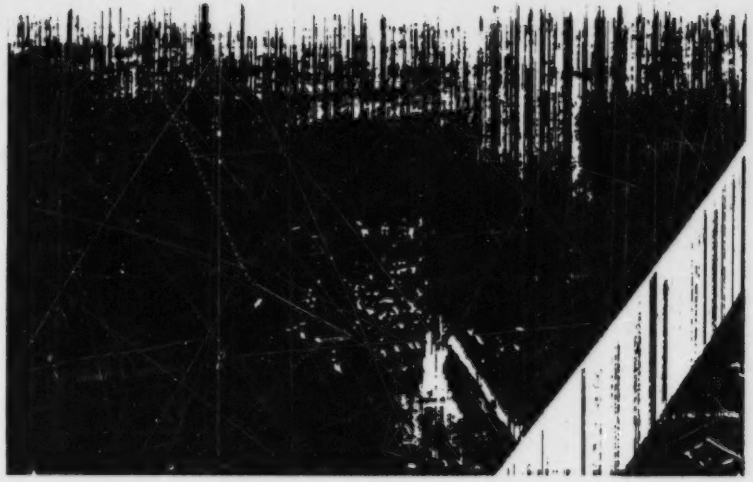

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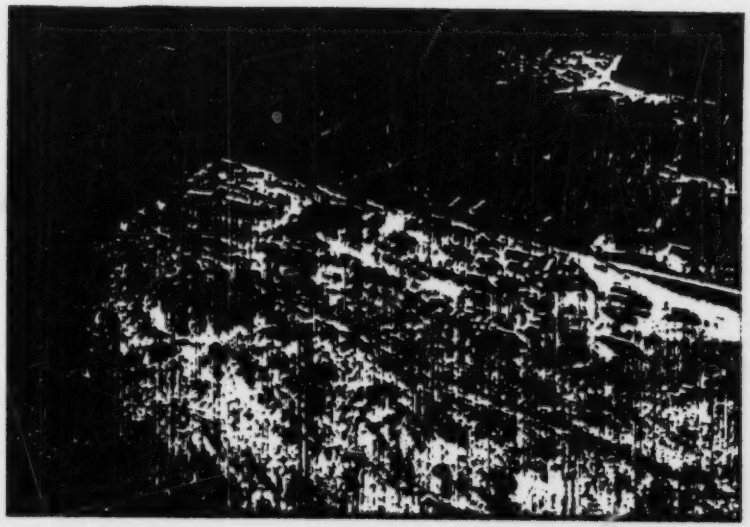

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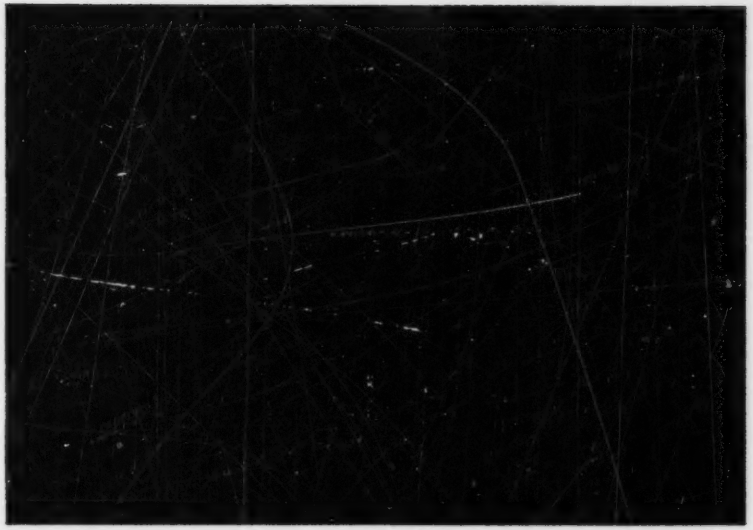

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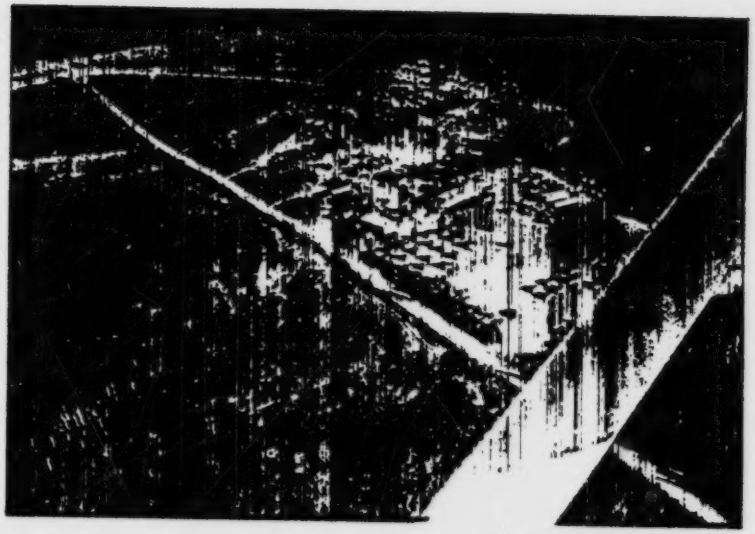

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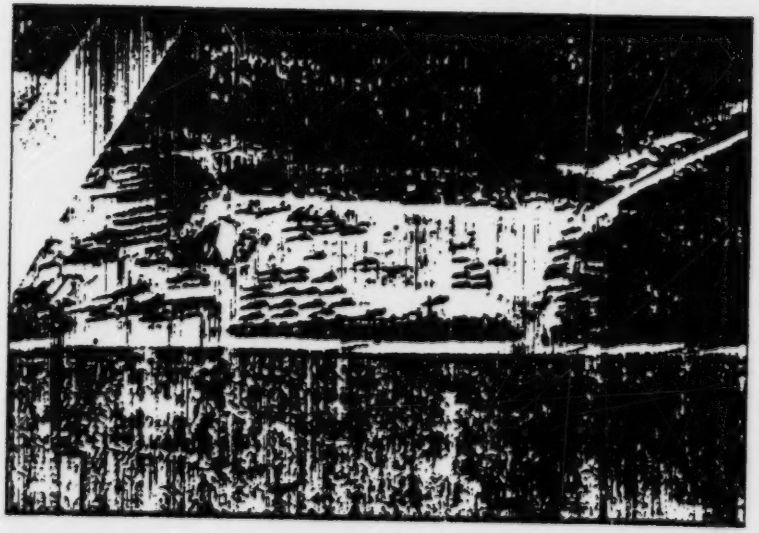

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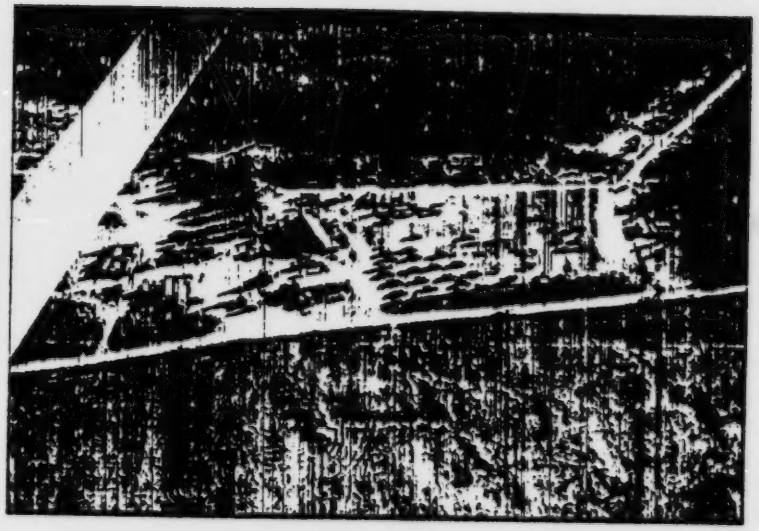

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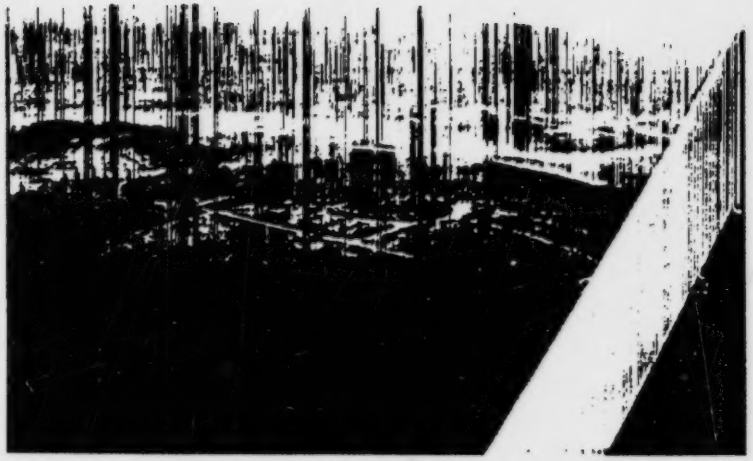

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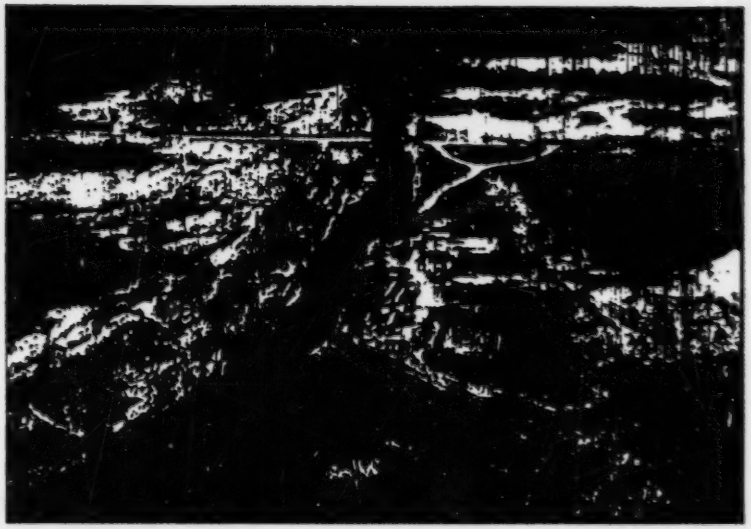

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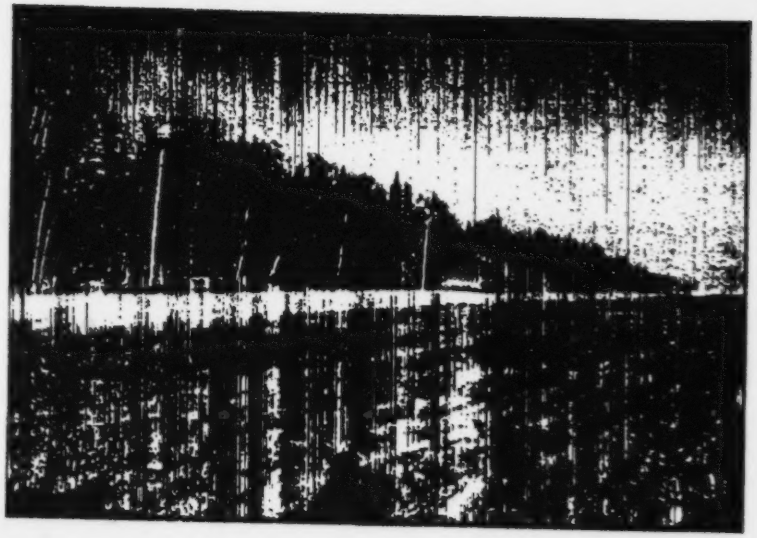

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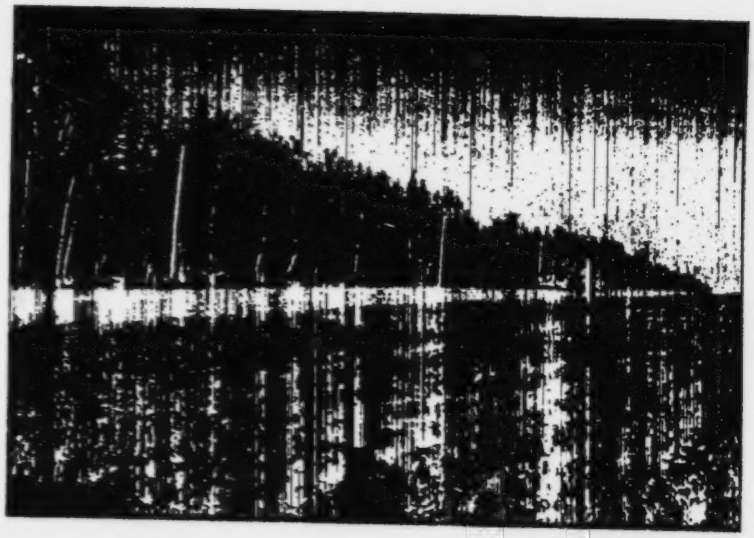

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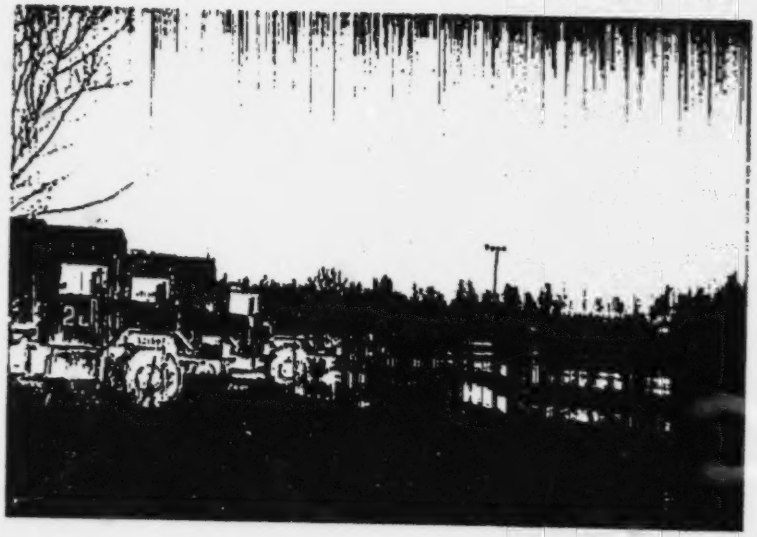

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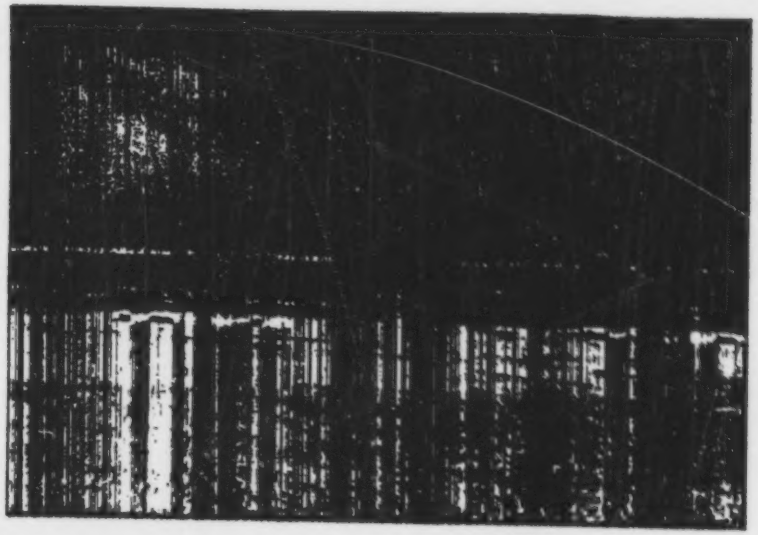

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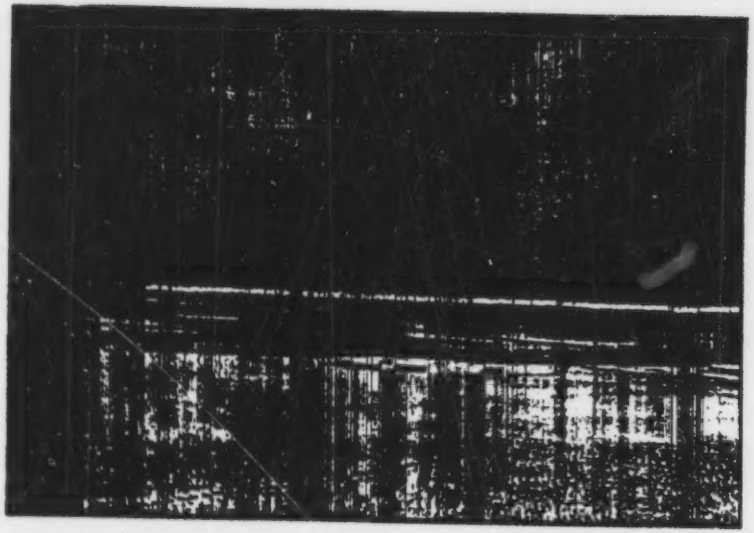

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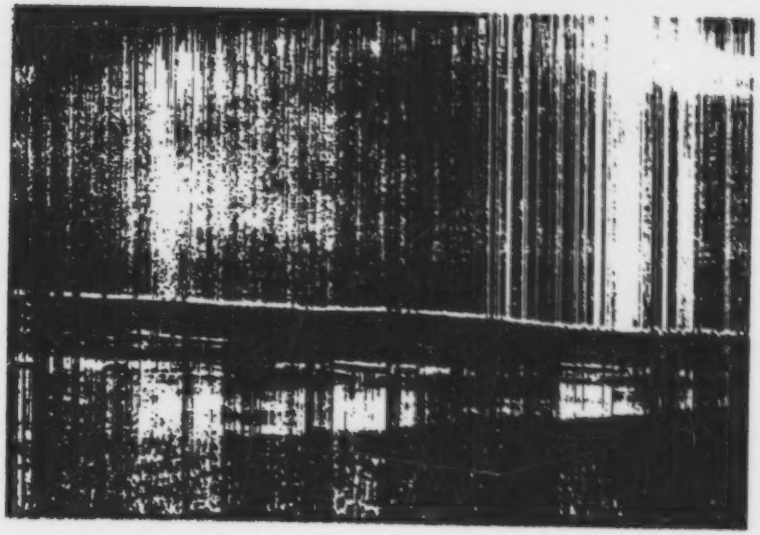

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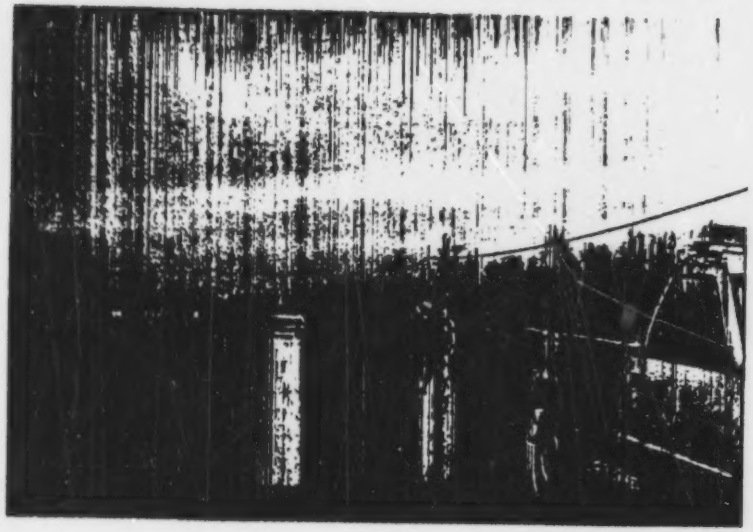

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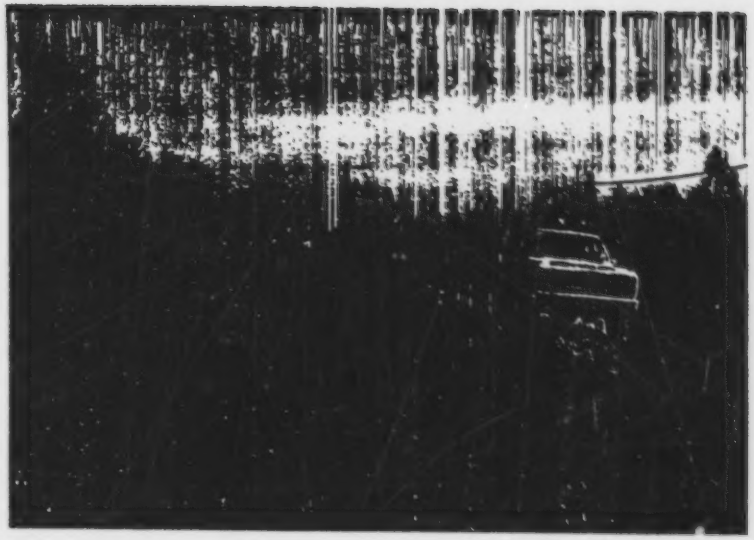

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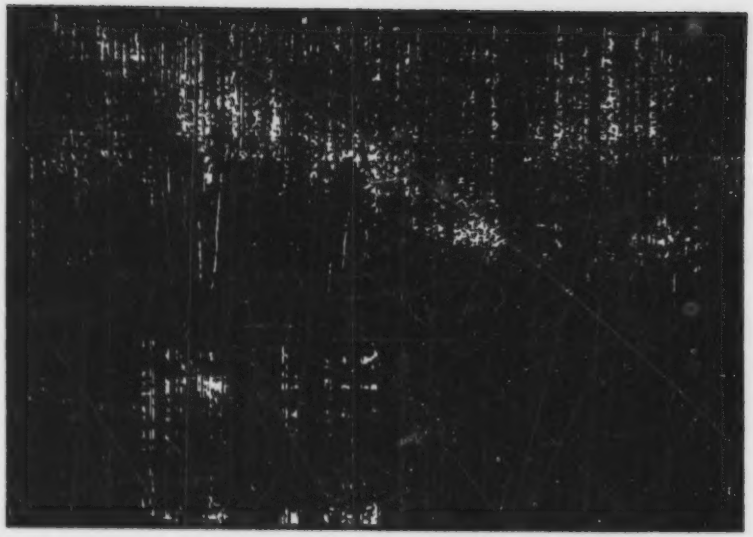

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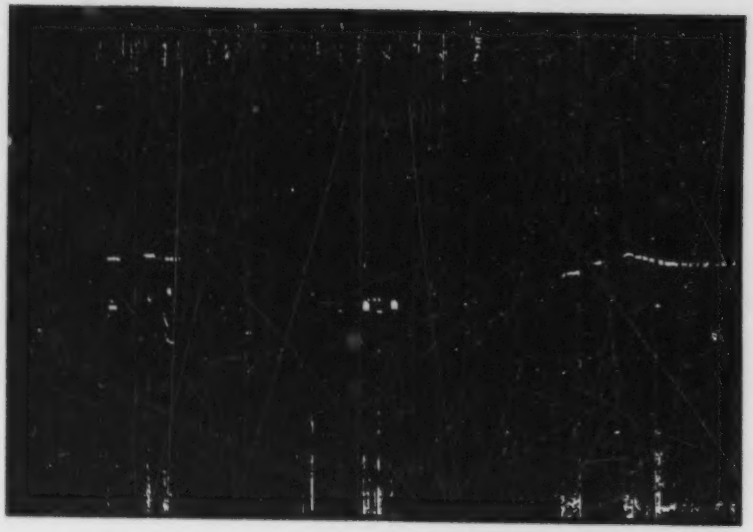

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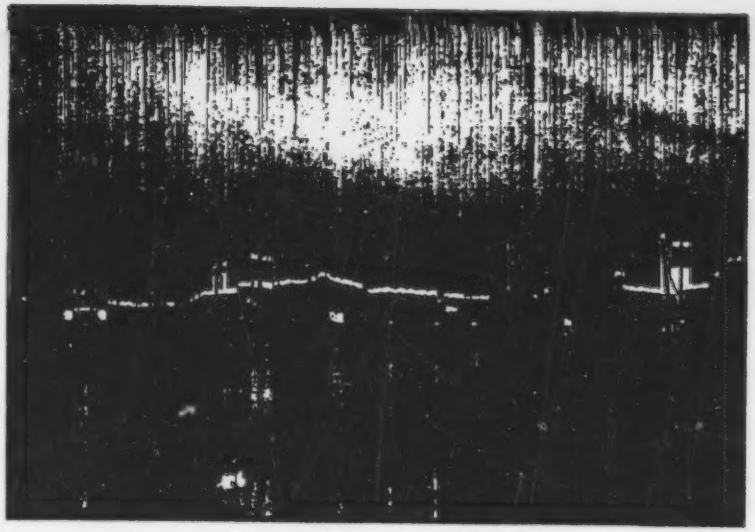

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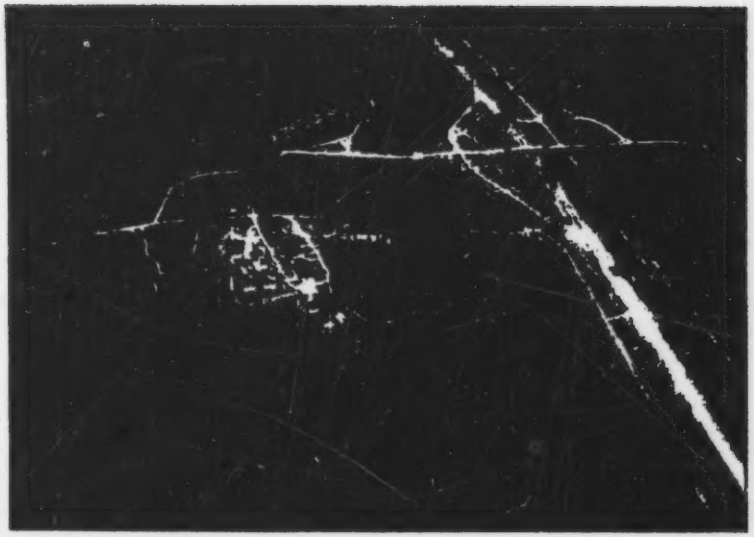

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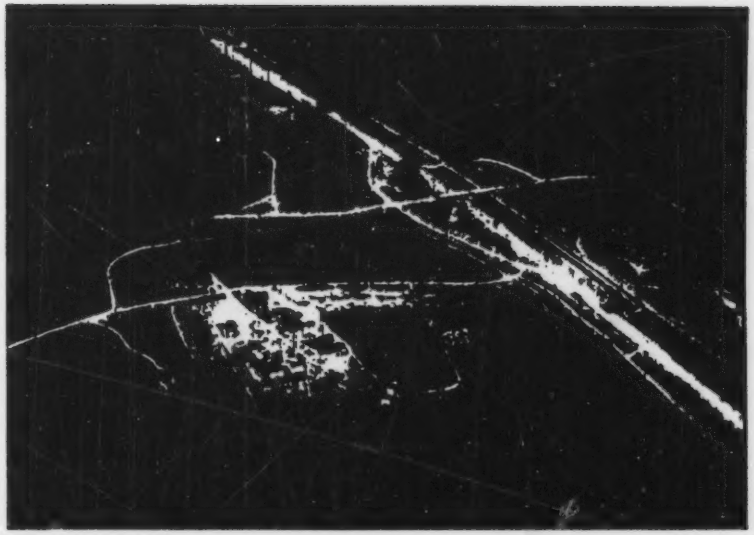

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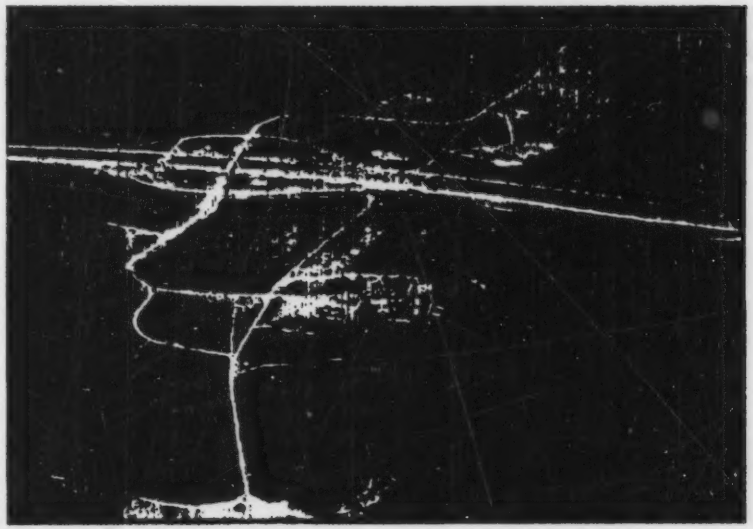

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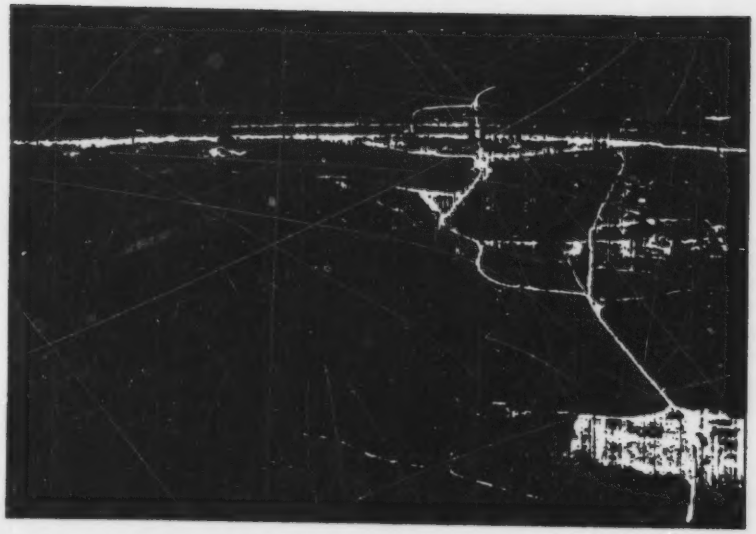

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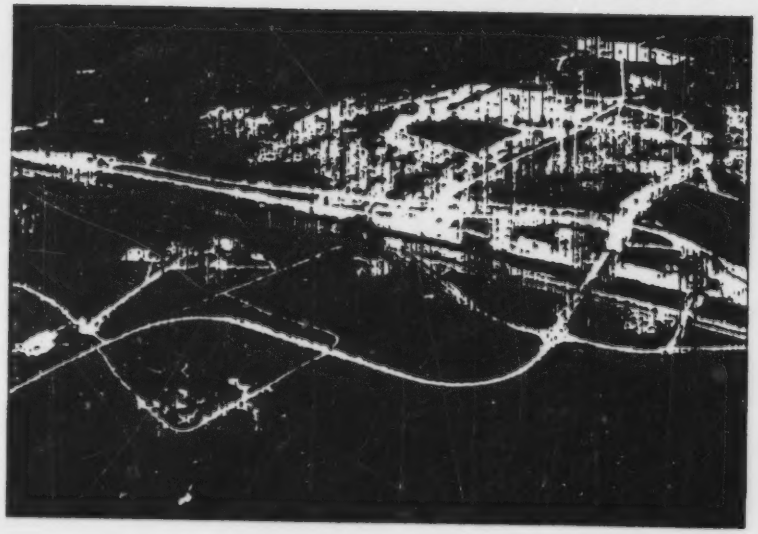
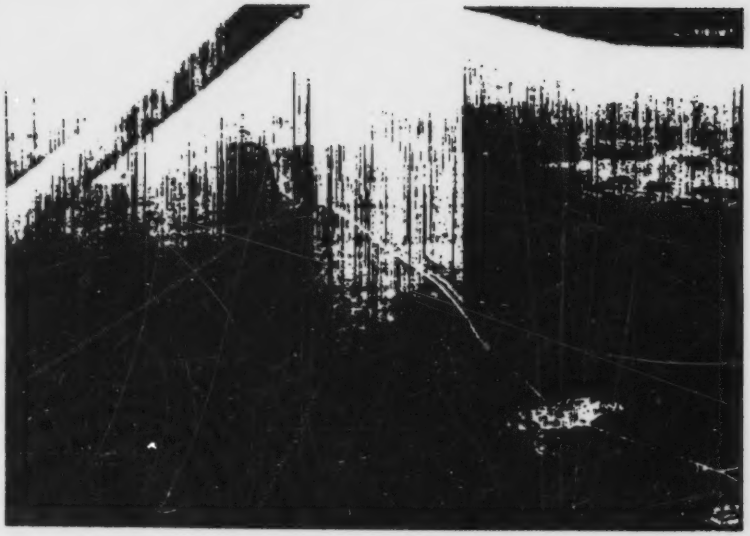


31 Jul '96 No. 07

31 Jul '96 No. 08



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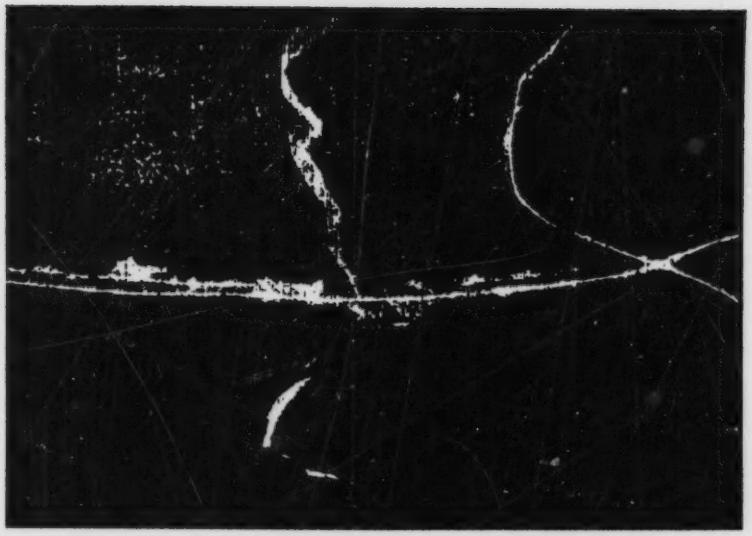

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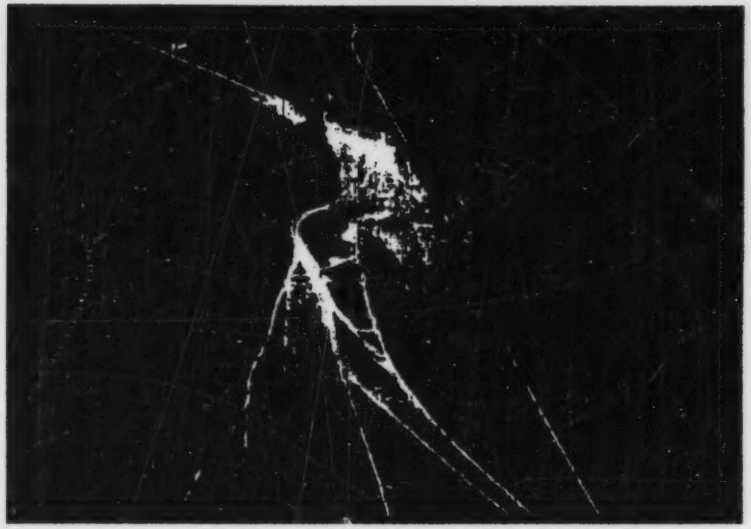

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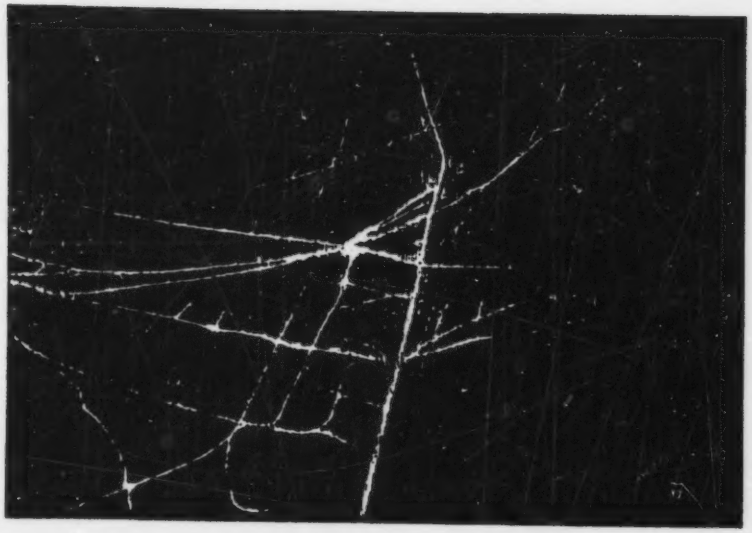

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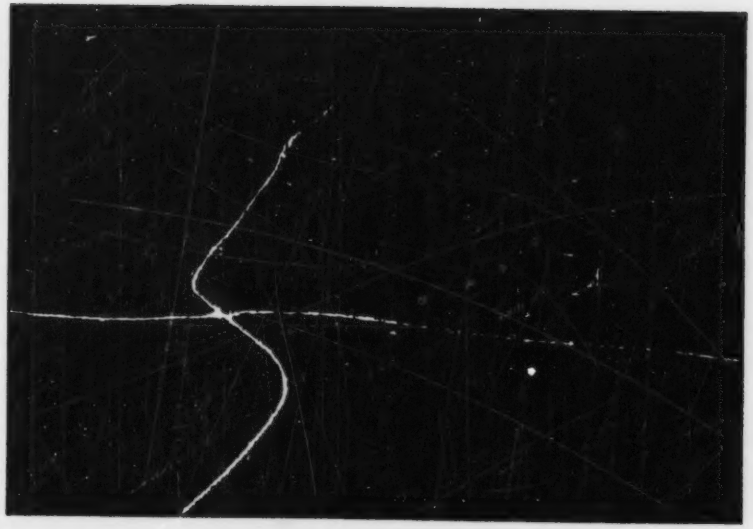

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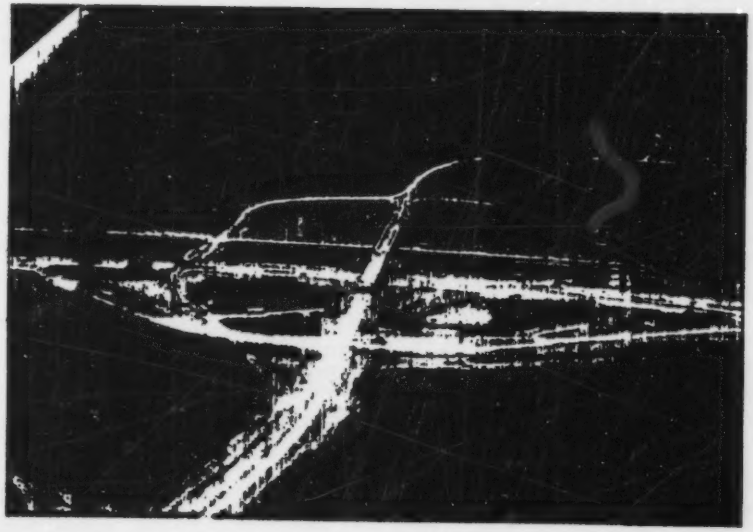

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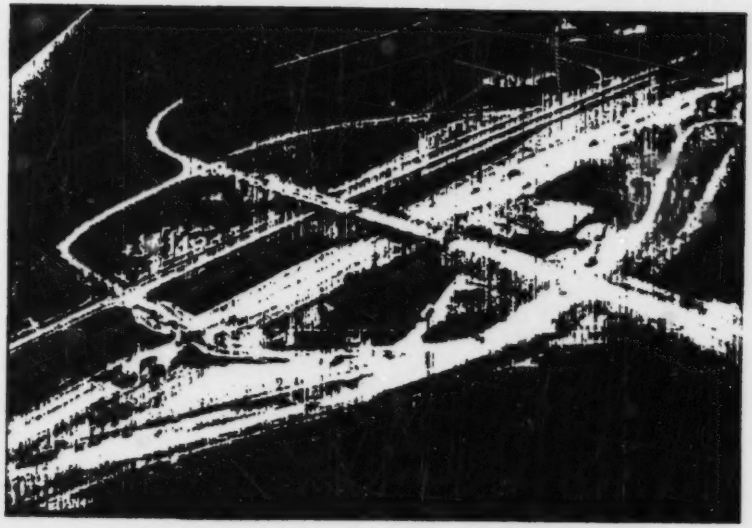

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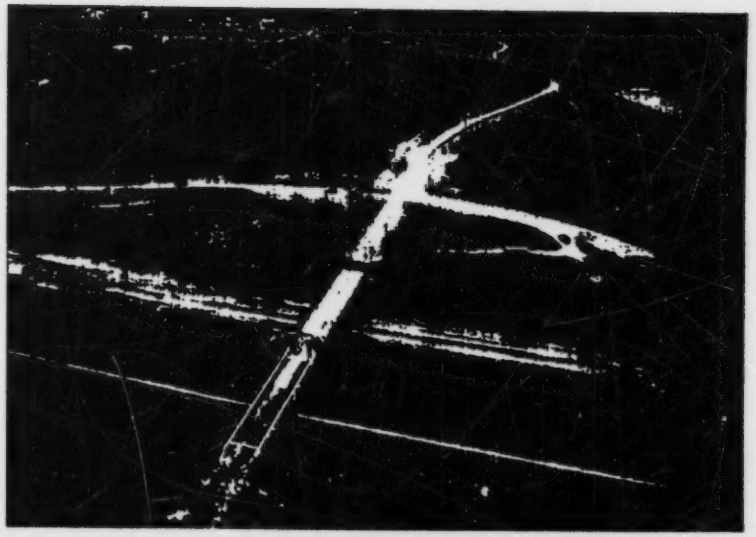

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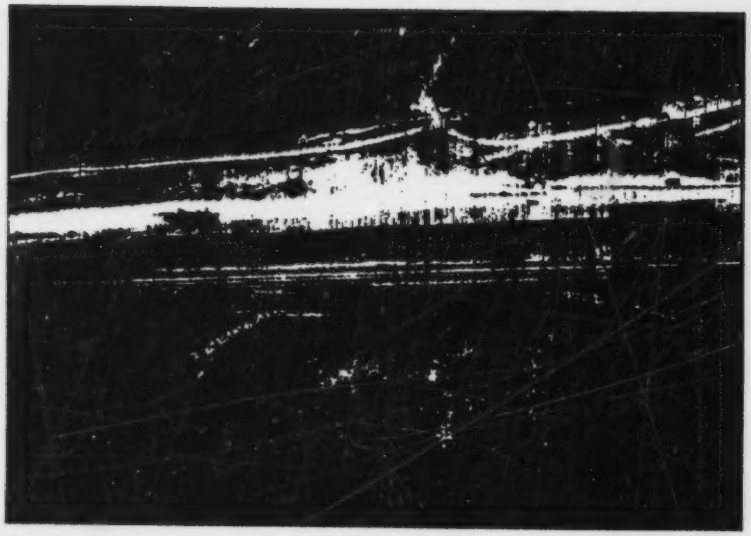

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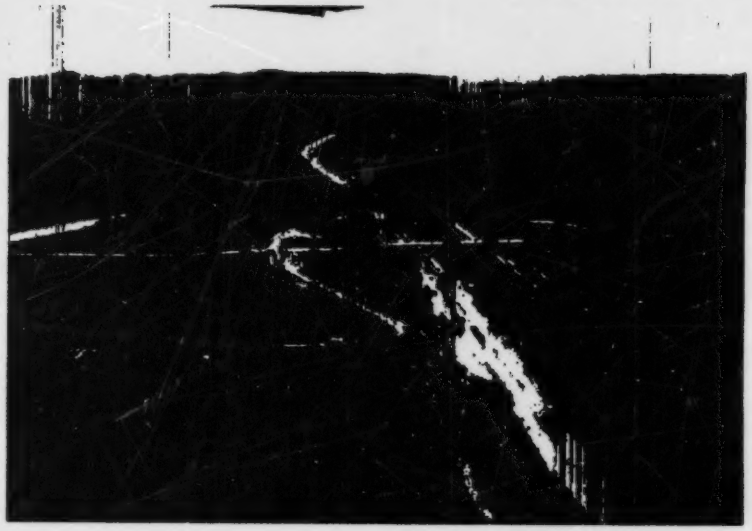

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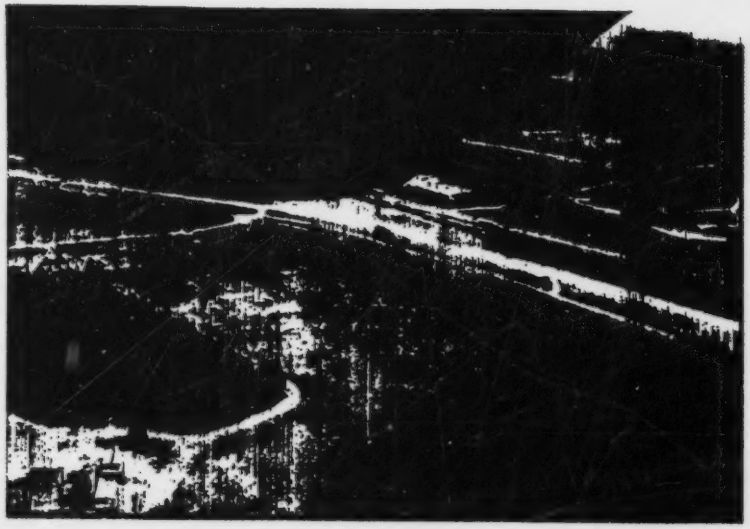

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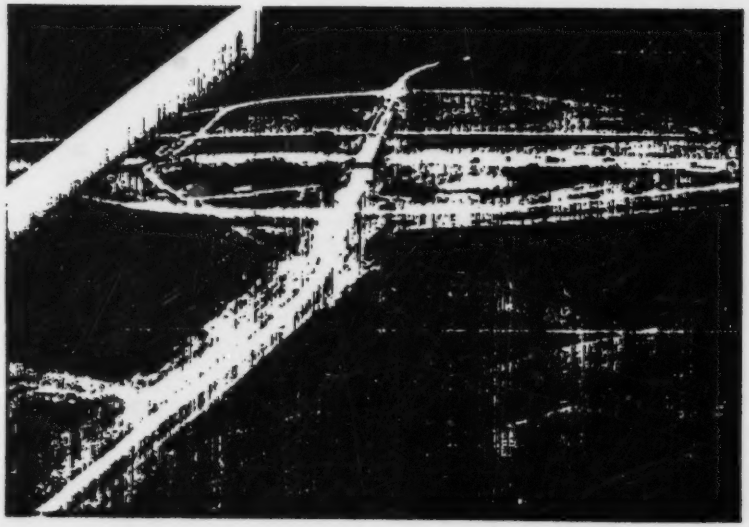

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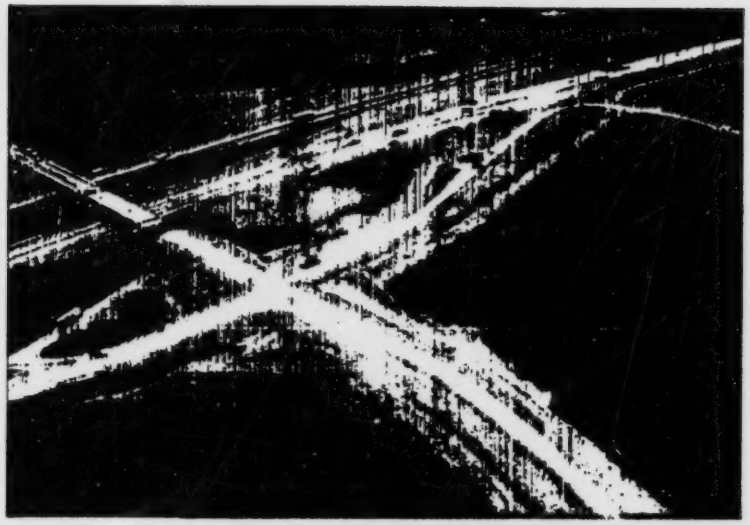

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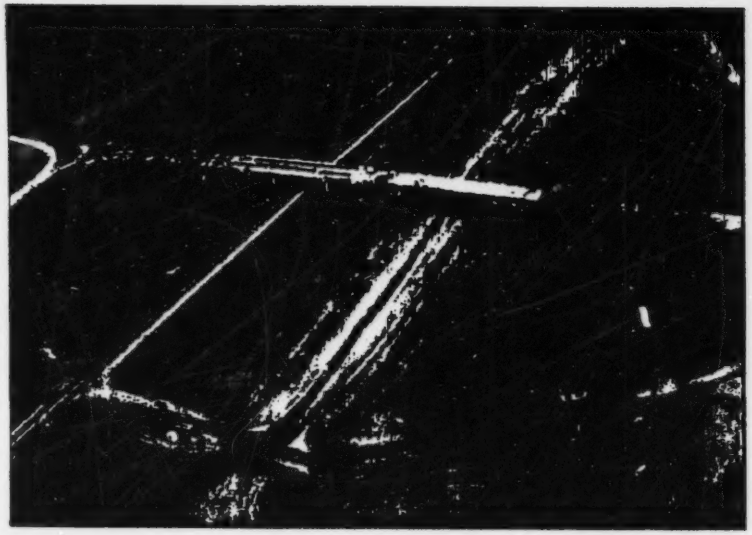

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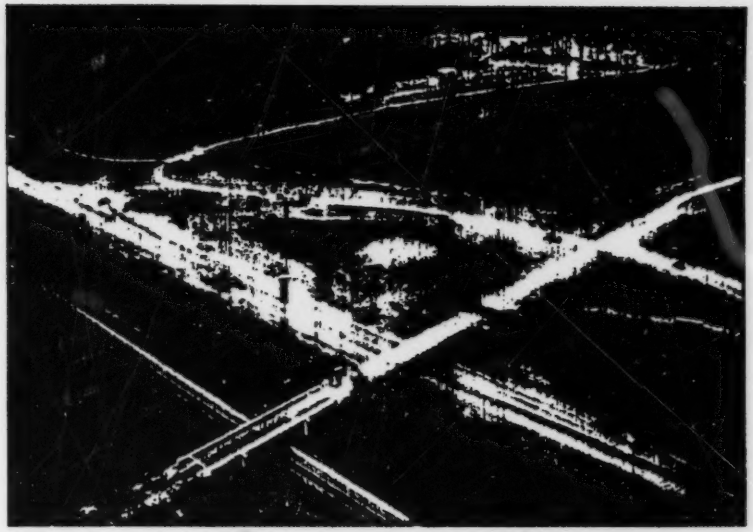

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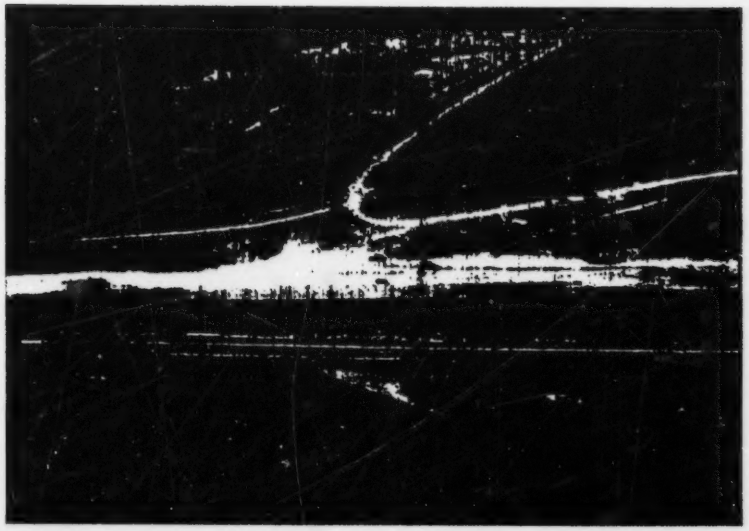

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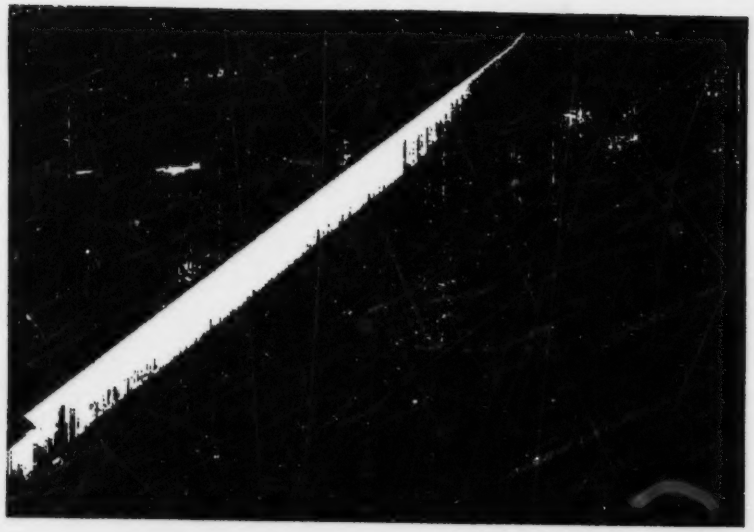

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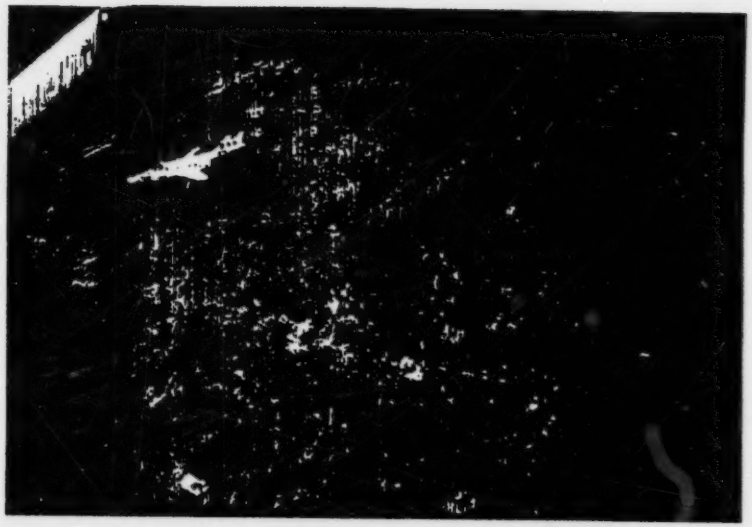

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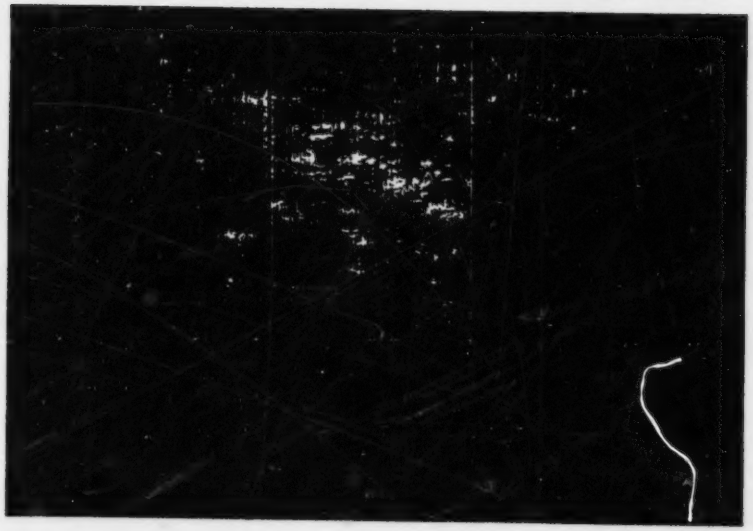

31 Jul '96 No. 31

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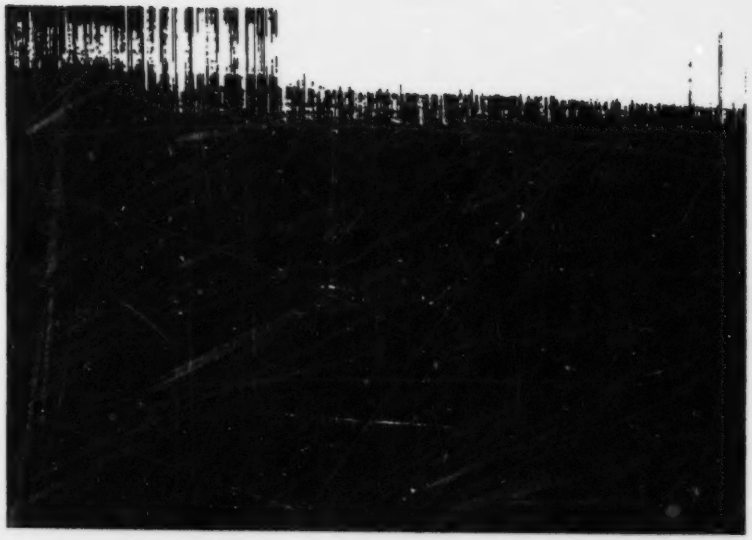

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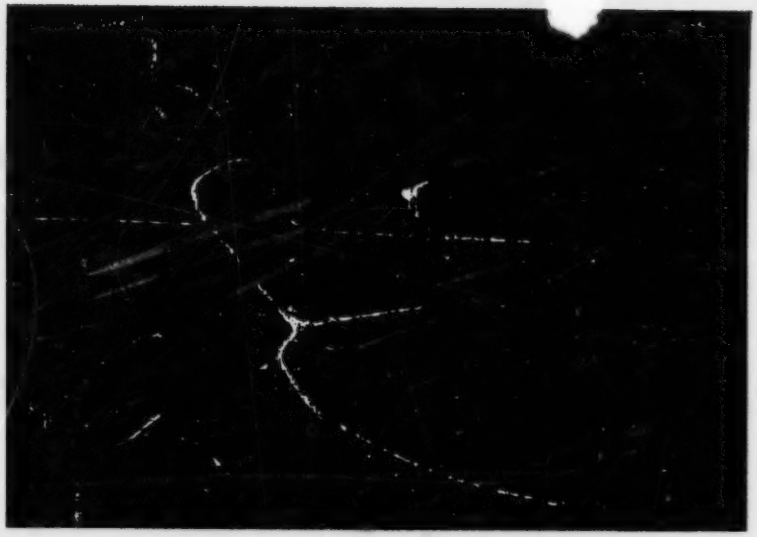

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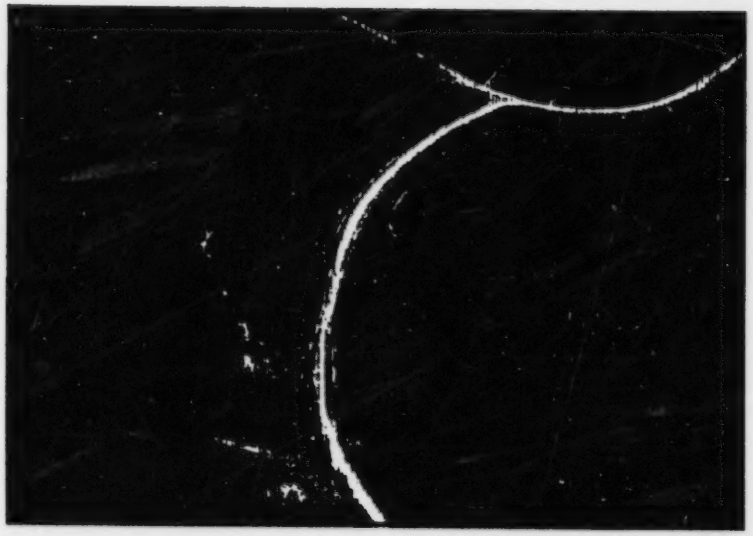

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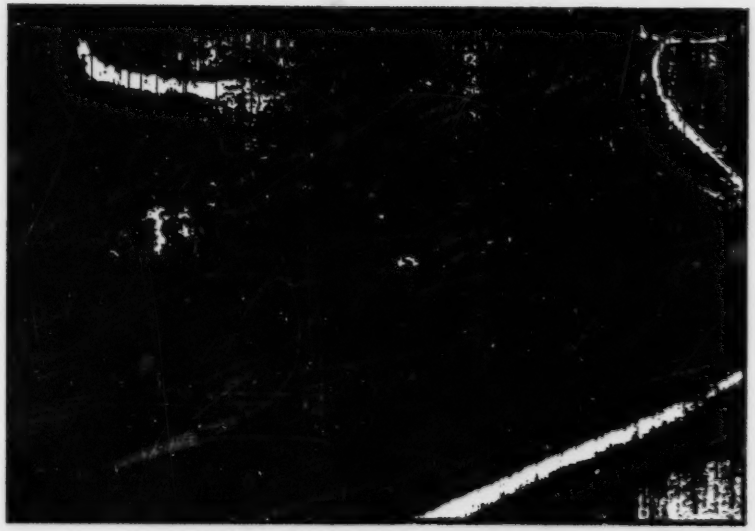

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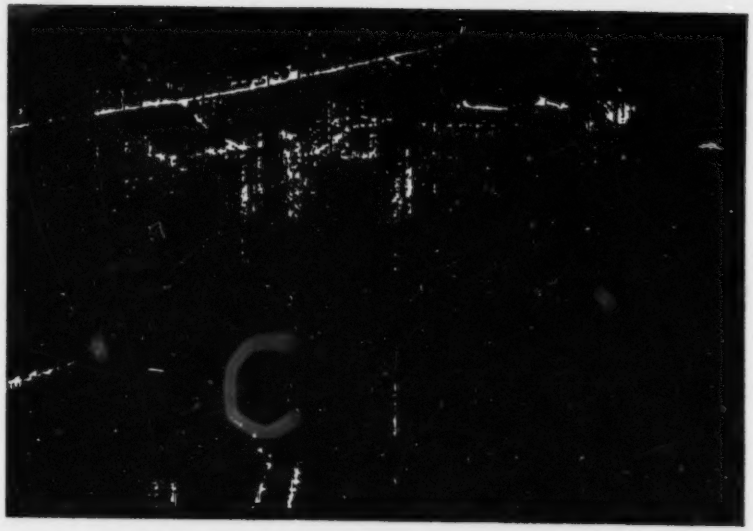

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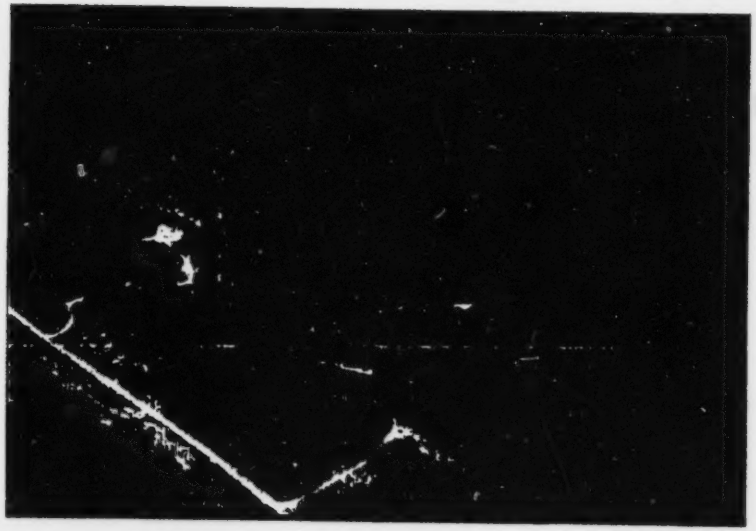

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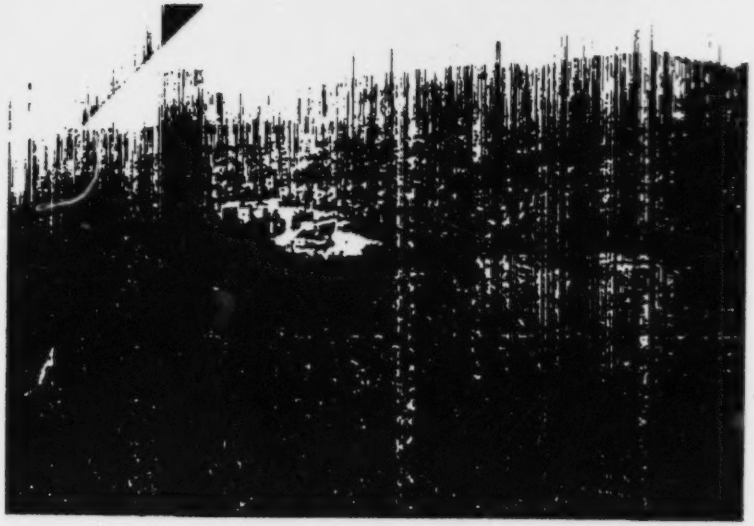

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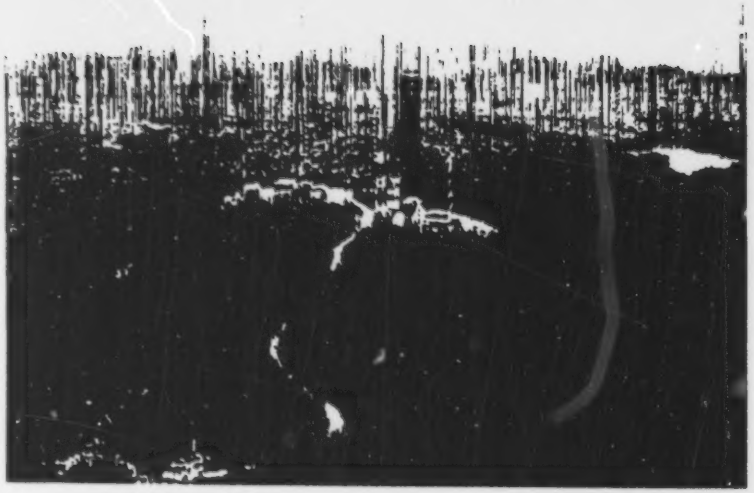
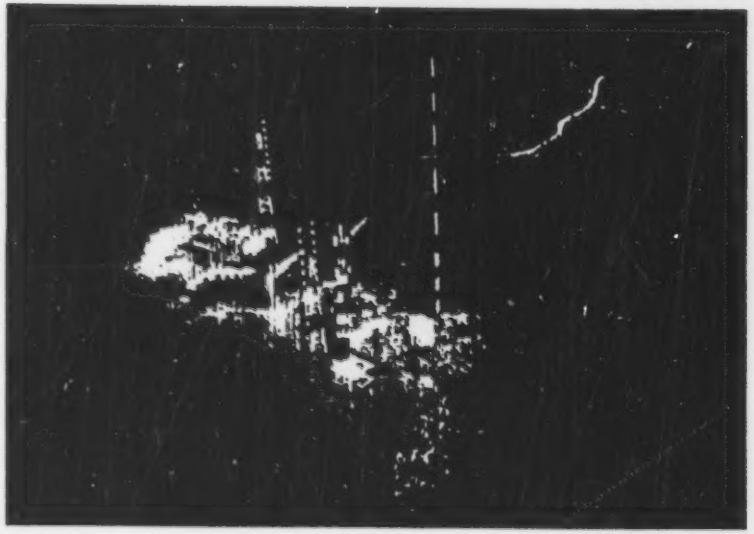


31 Jul '96 No. 41

31 Jul '96 No. 42



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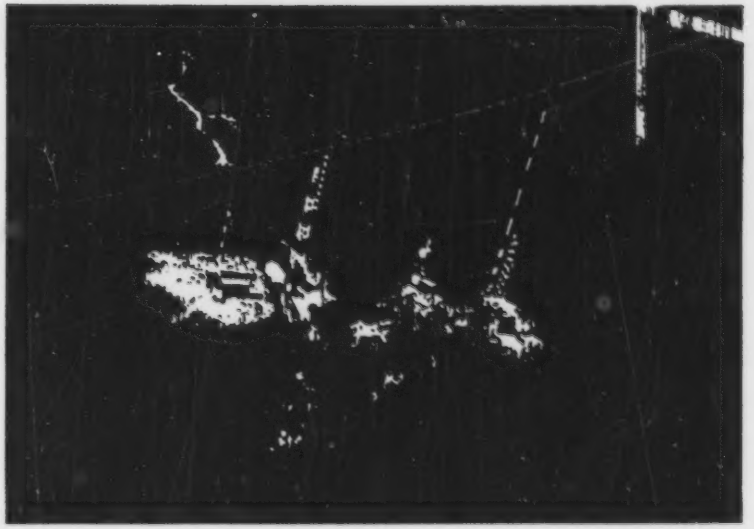

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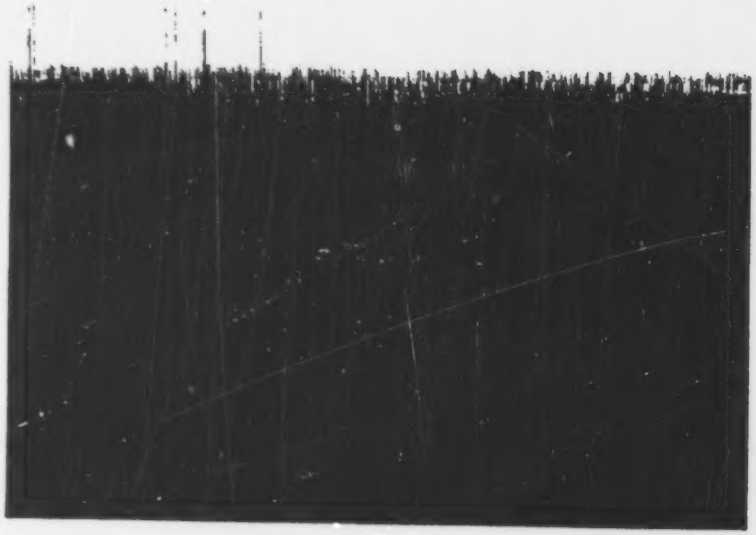

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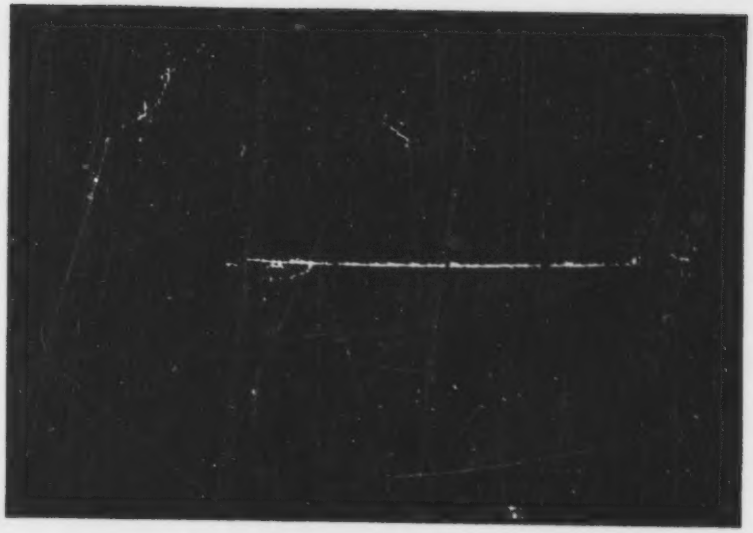

31 Jul '96 No. 46

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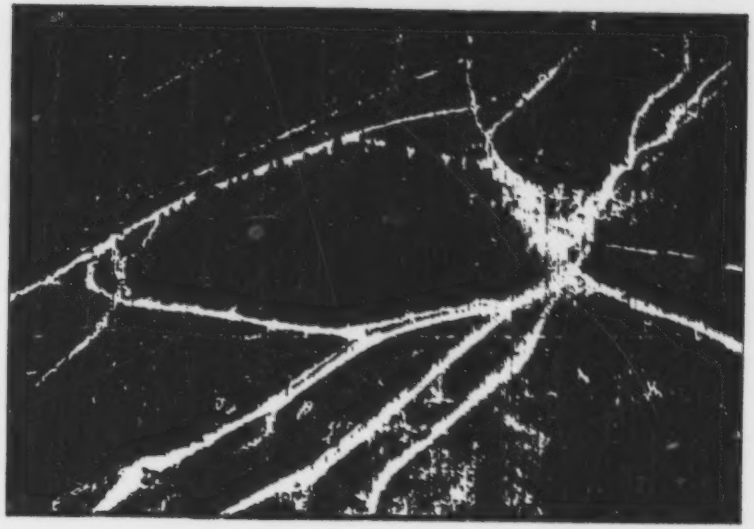

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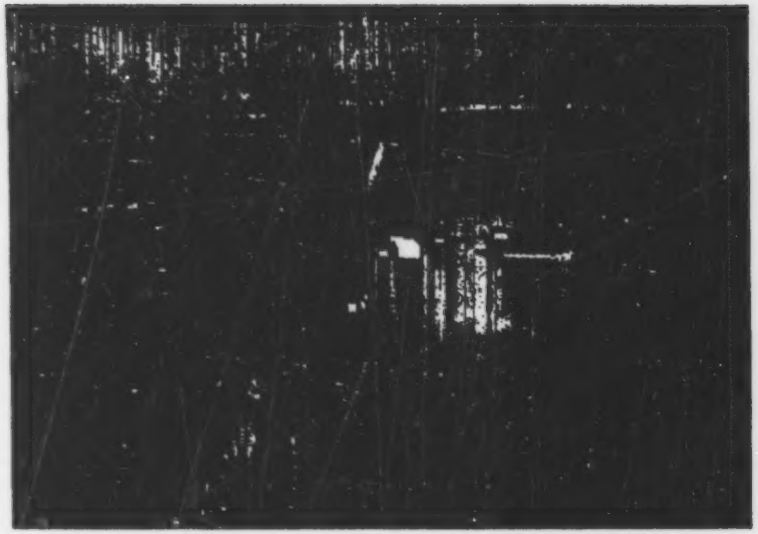

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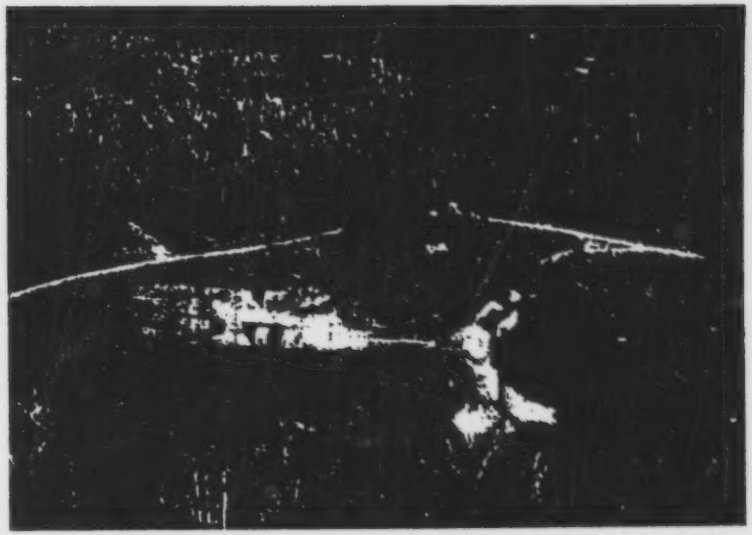

13 Aug '96 No. 22

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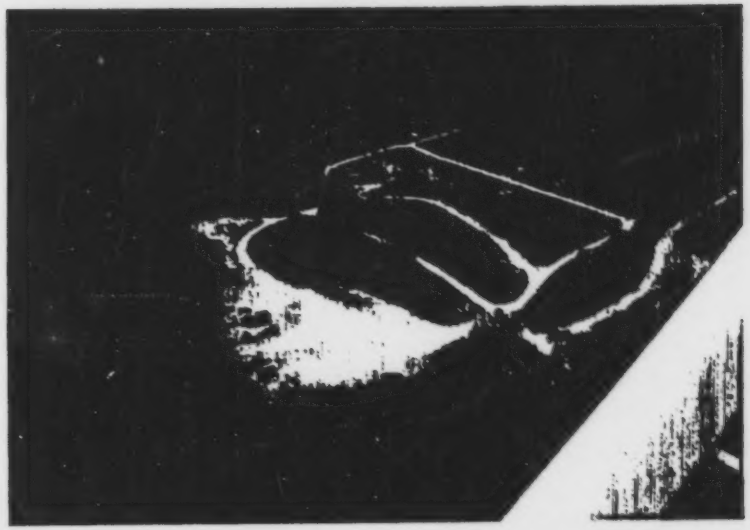

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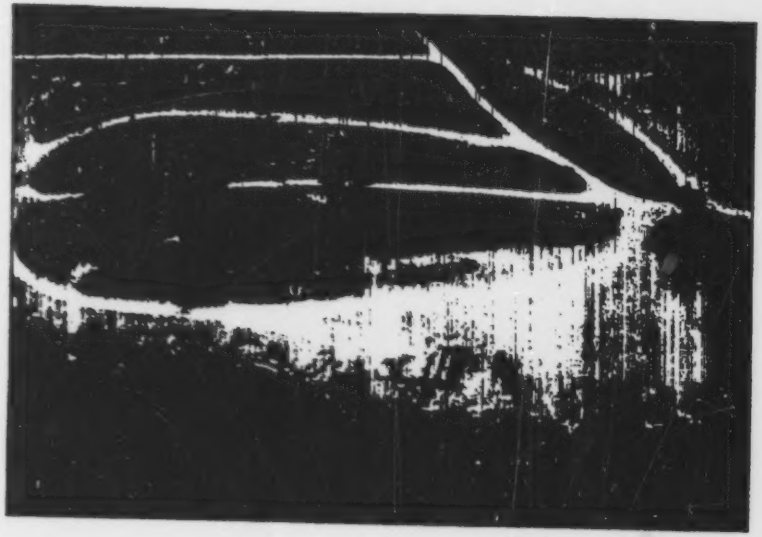

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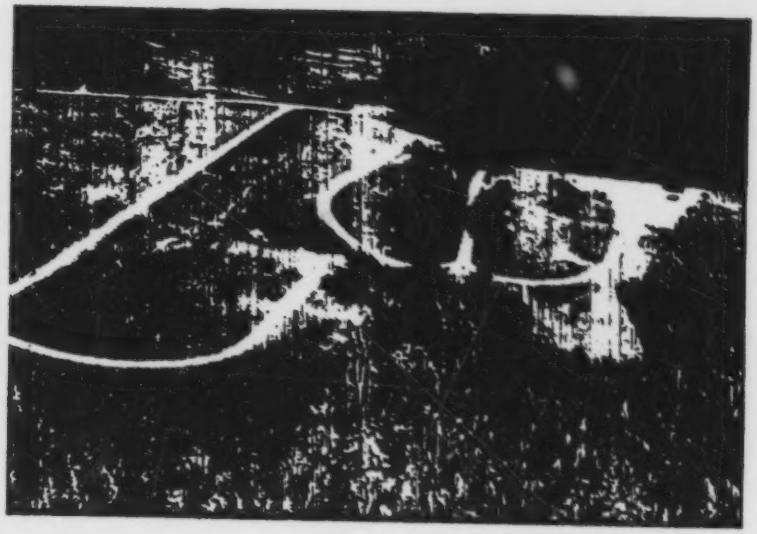

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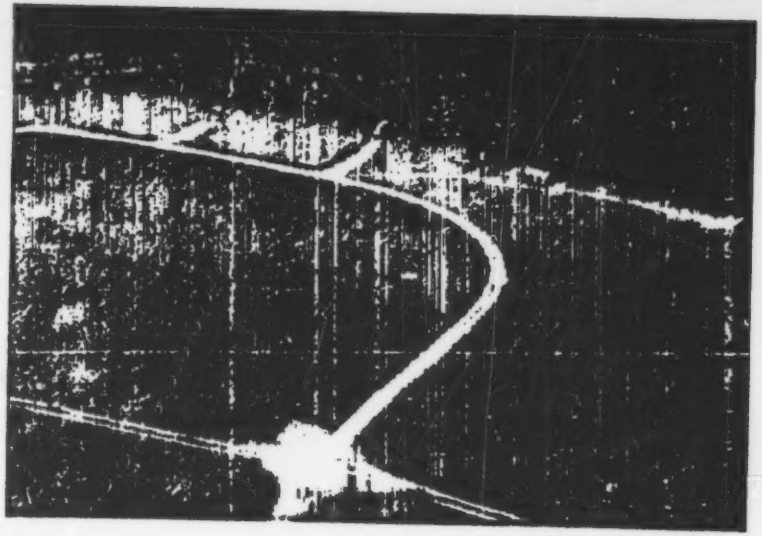

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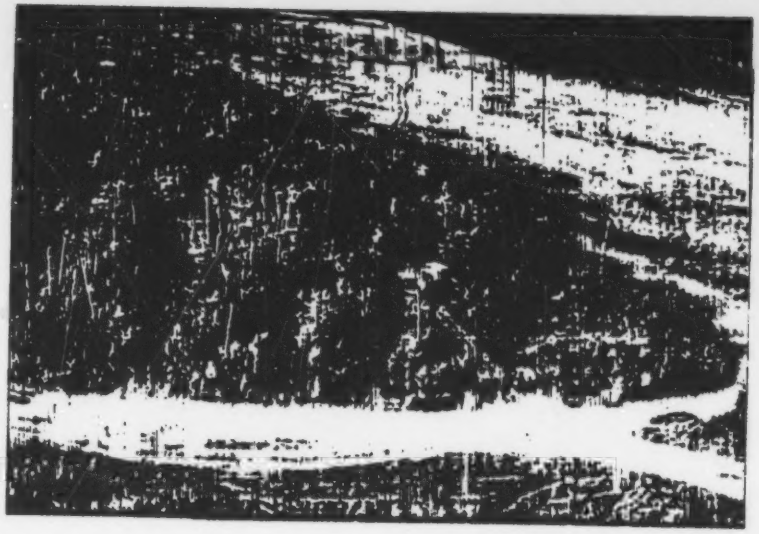

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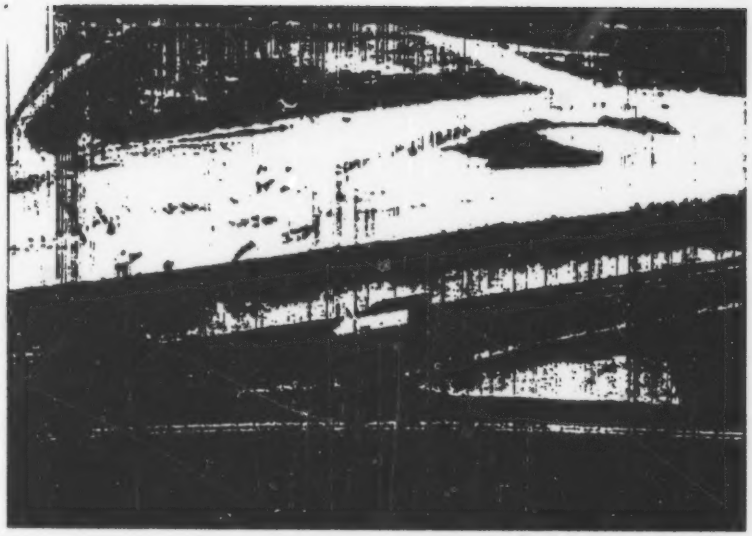

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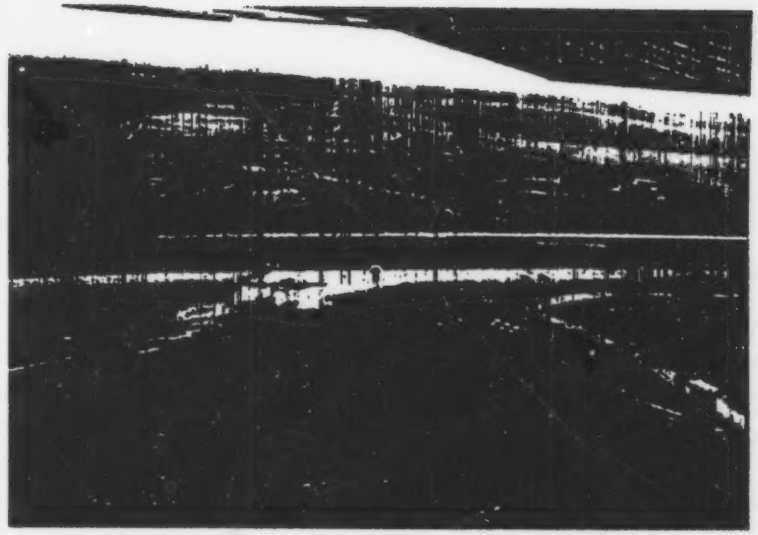

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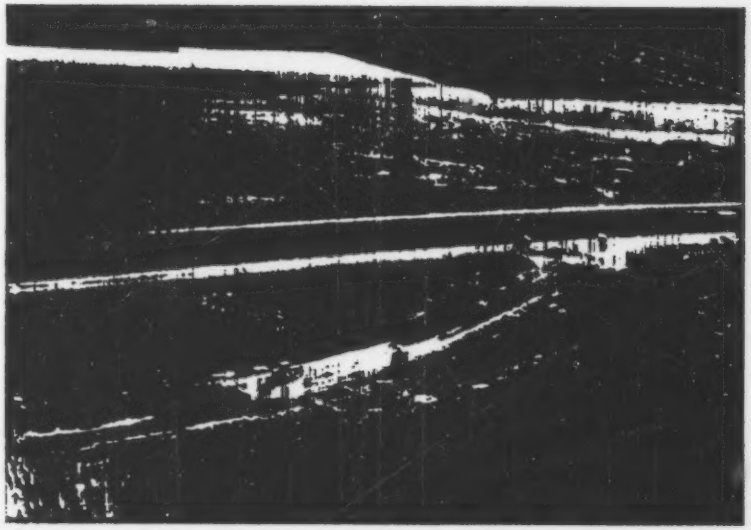

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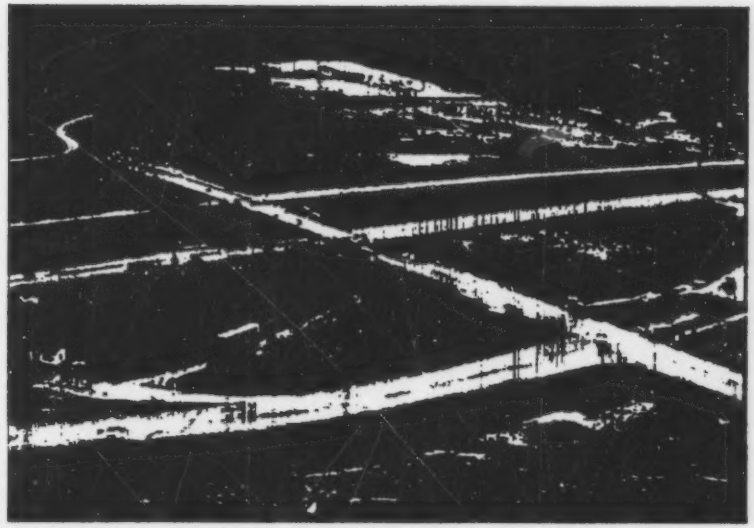

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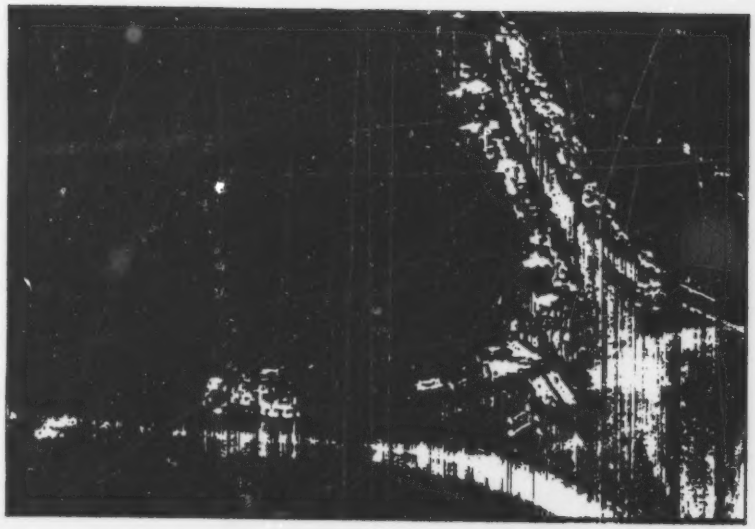

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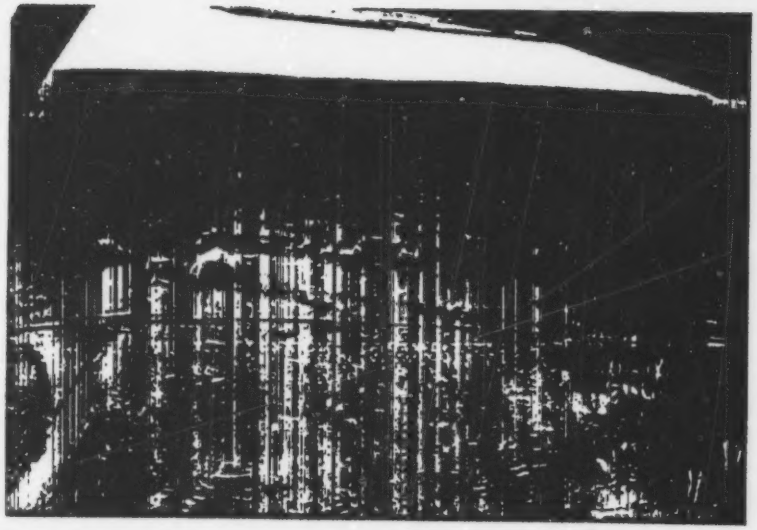

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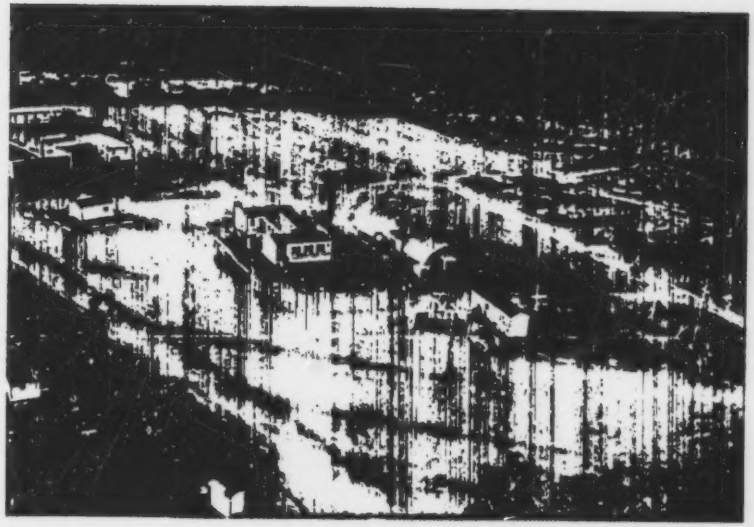

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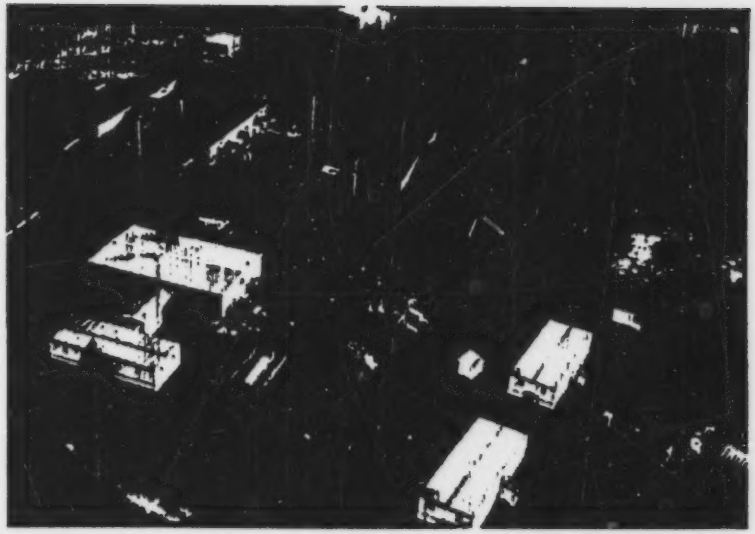

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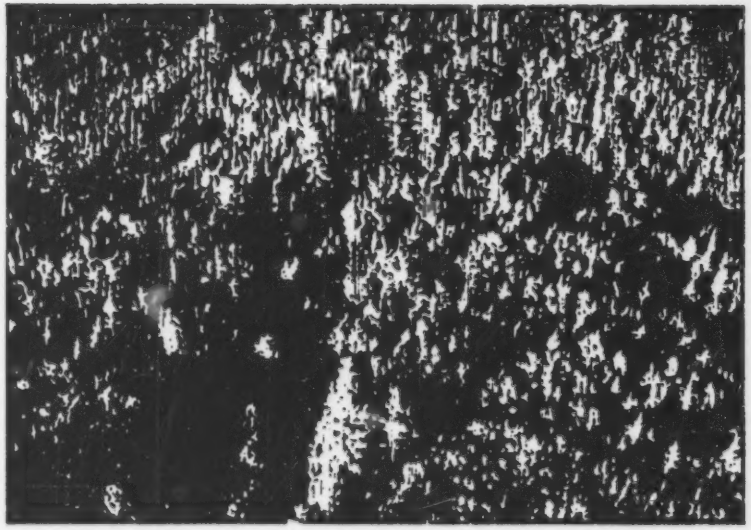

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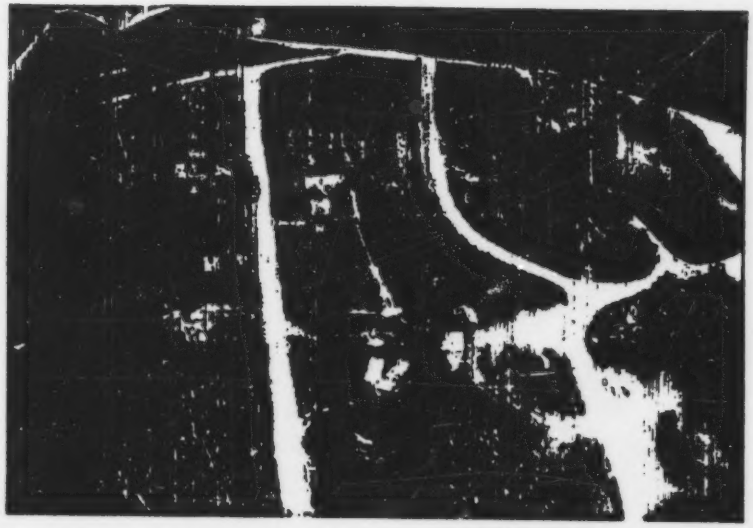

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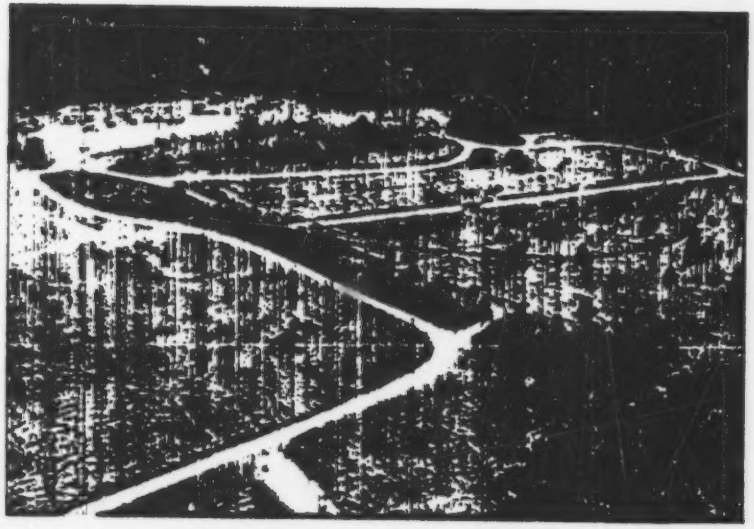

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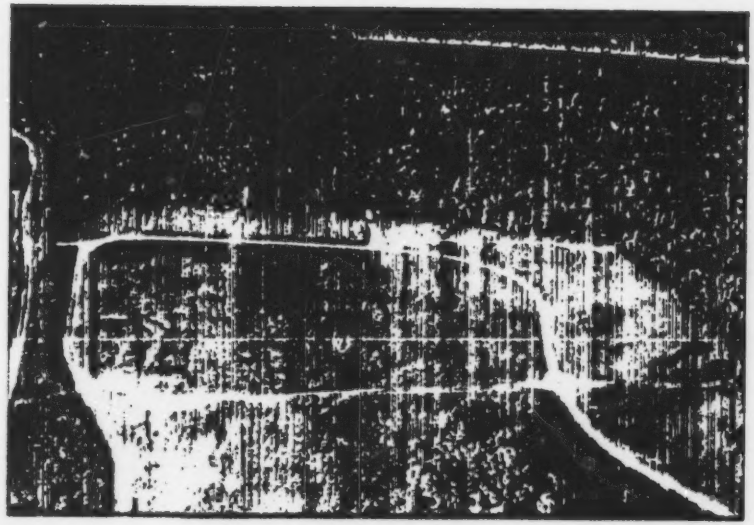

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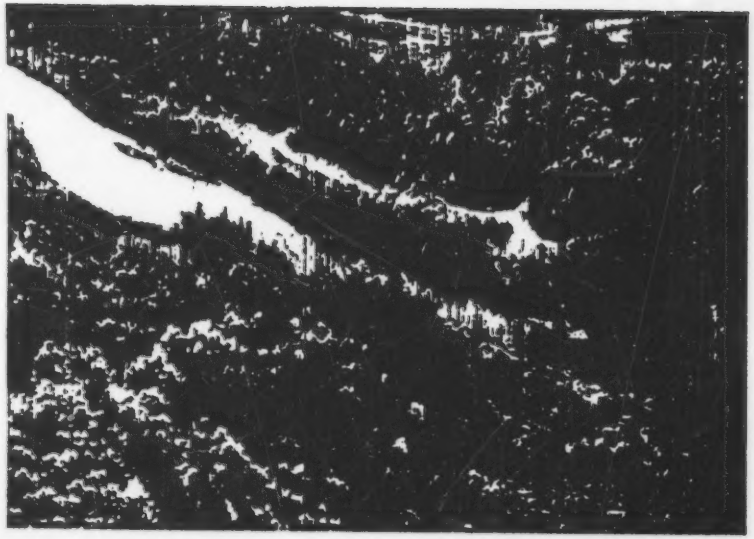

13 Aug '96 No. 45

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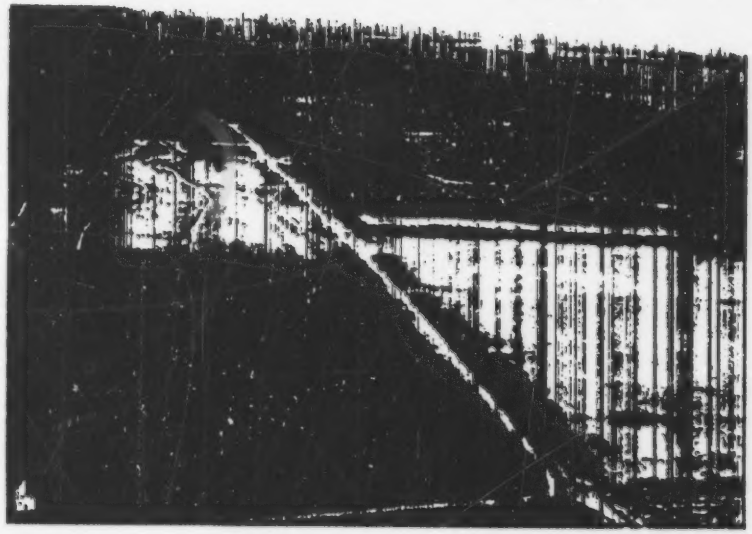

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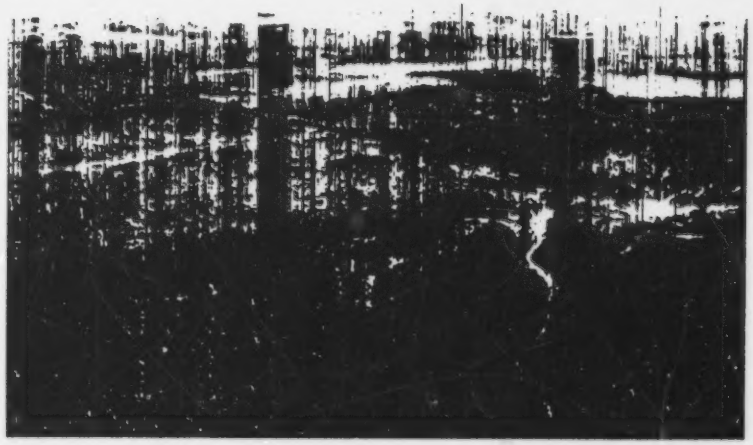
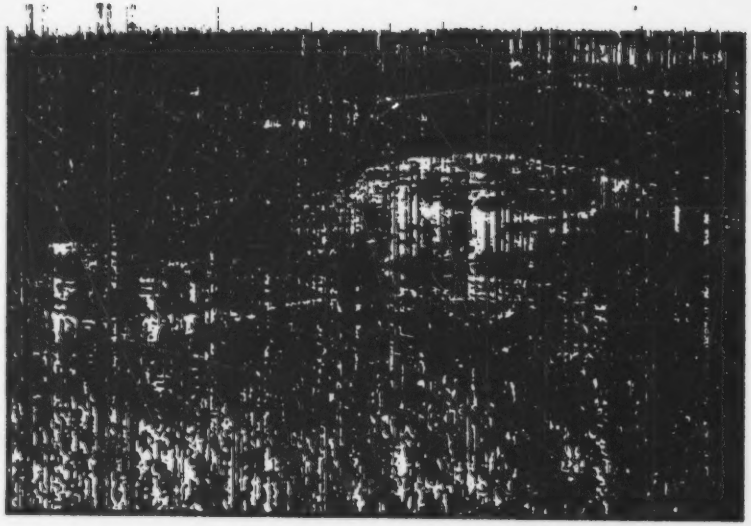


13 Aug '96 No. 48



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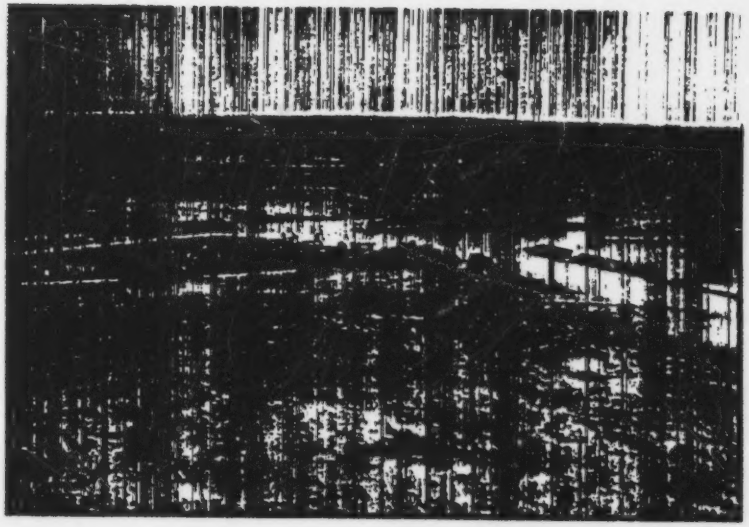

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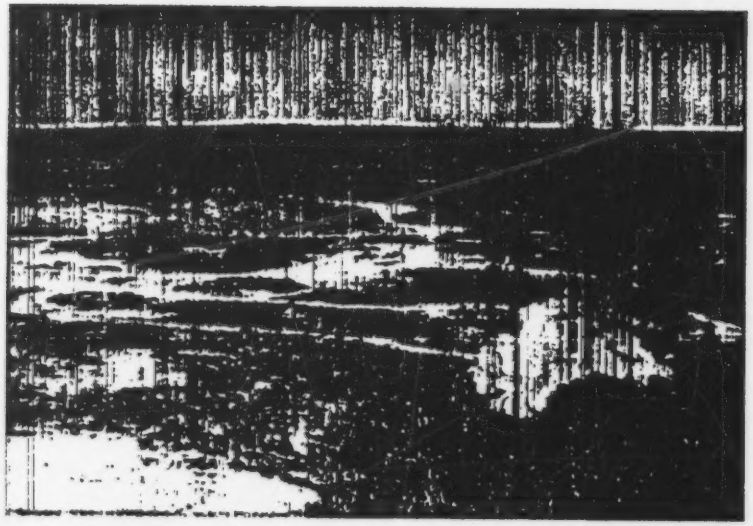

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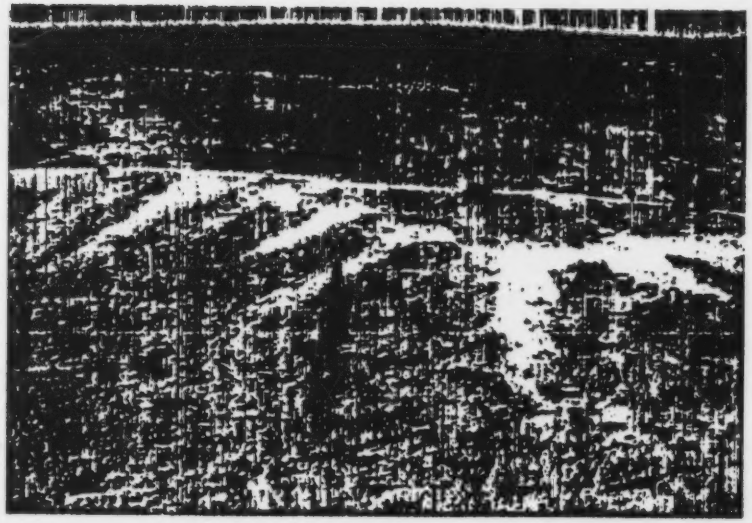

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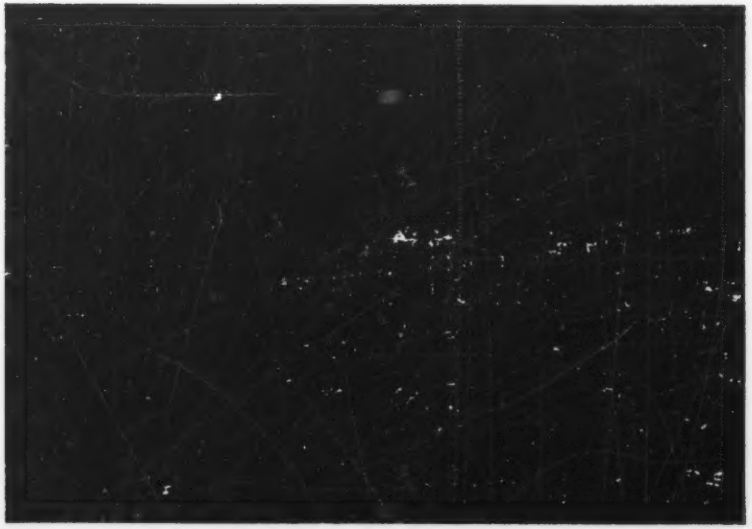

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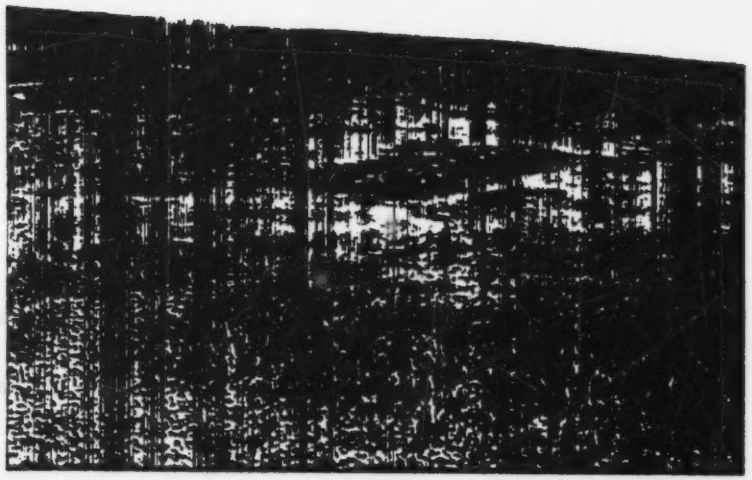

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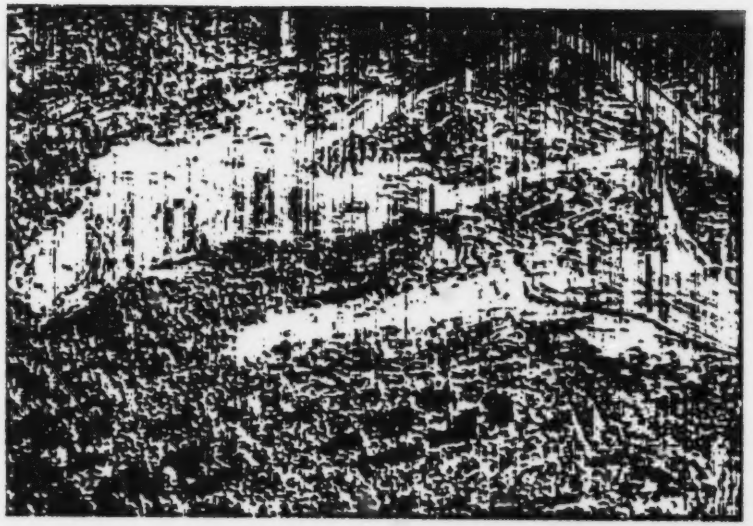

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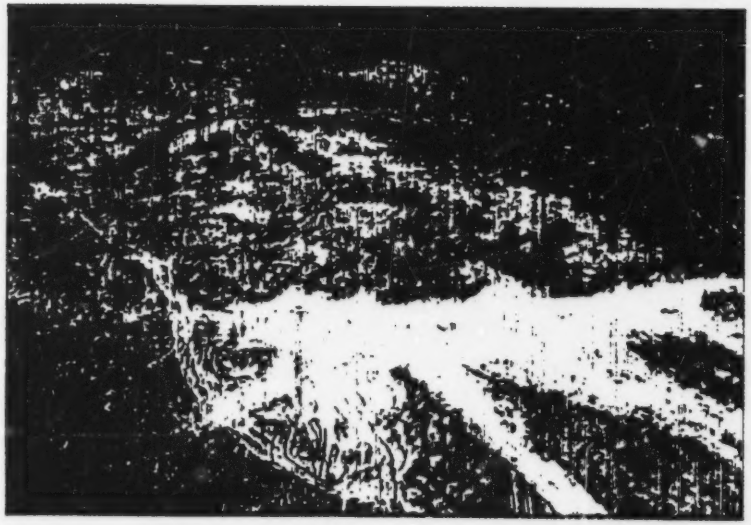

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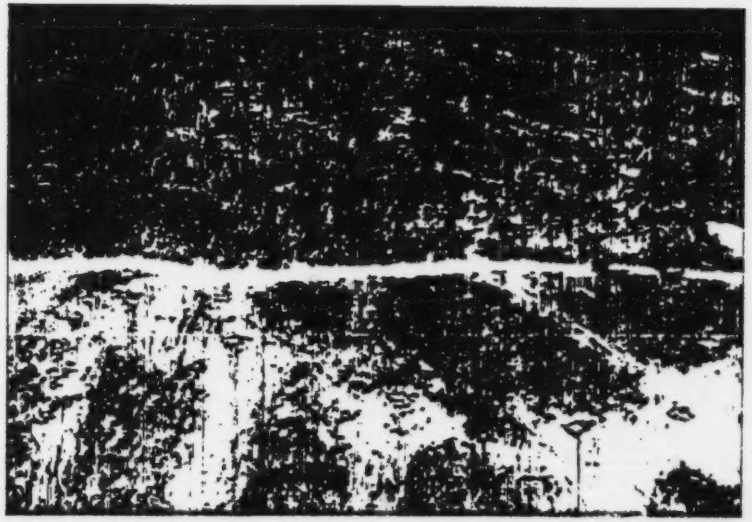

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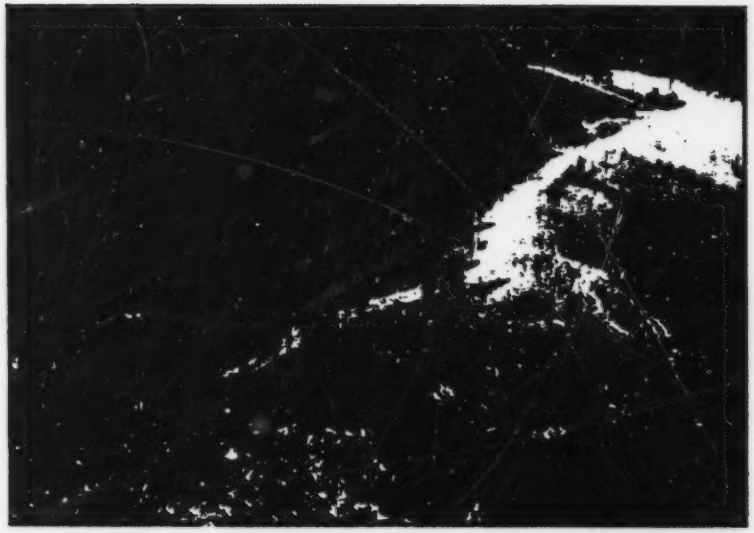

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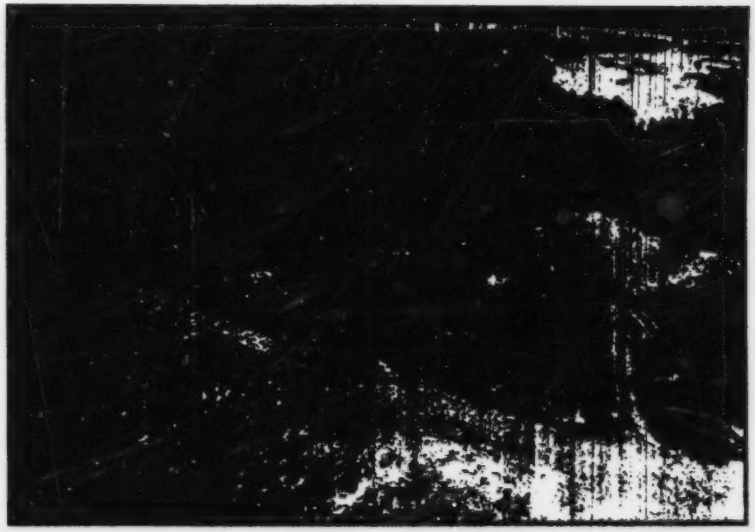

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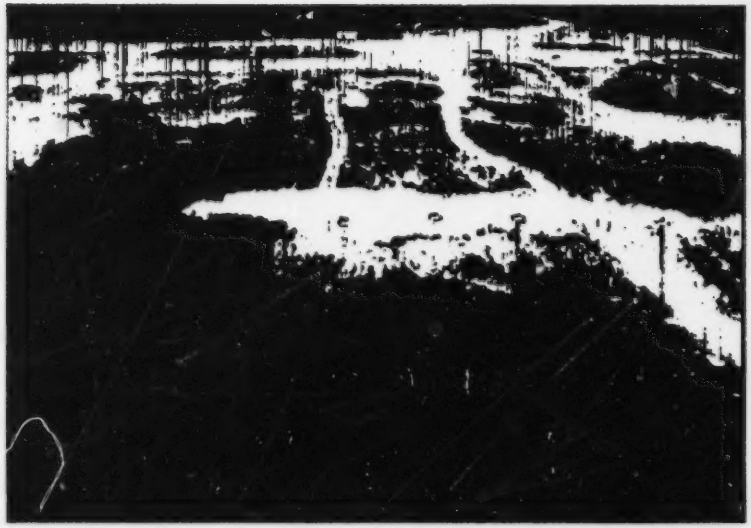

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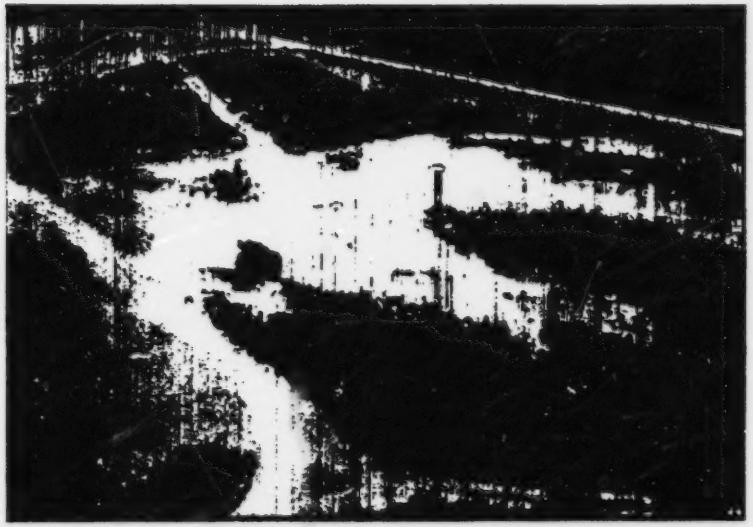

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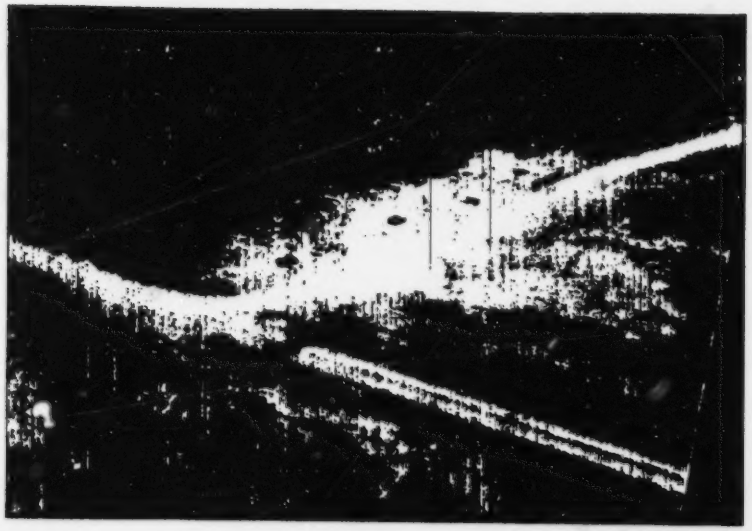

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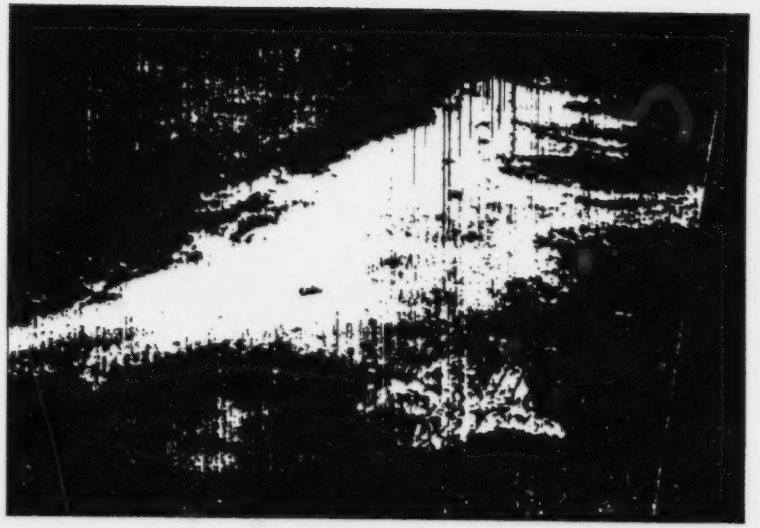

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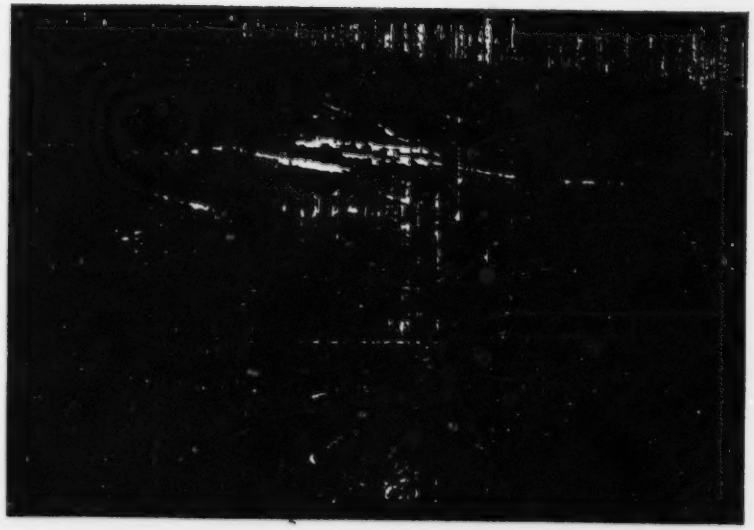

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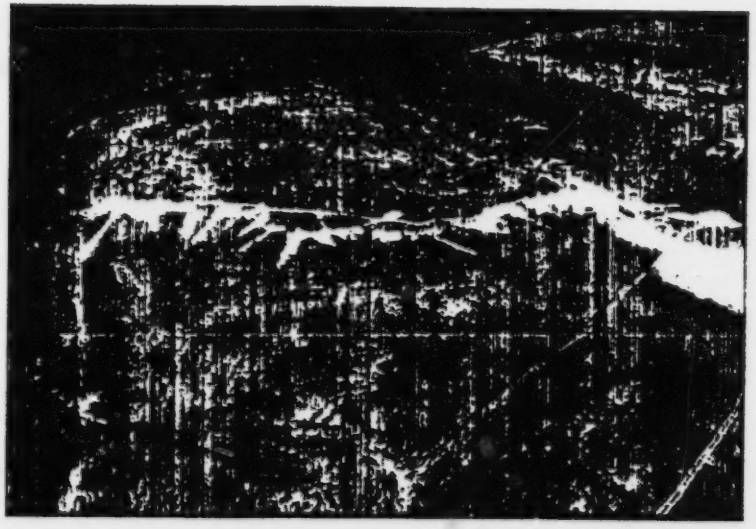

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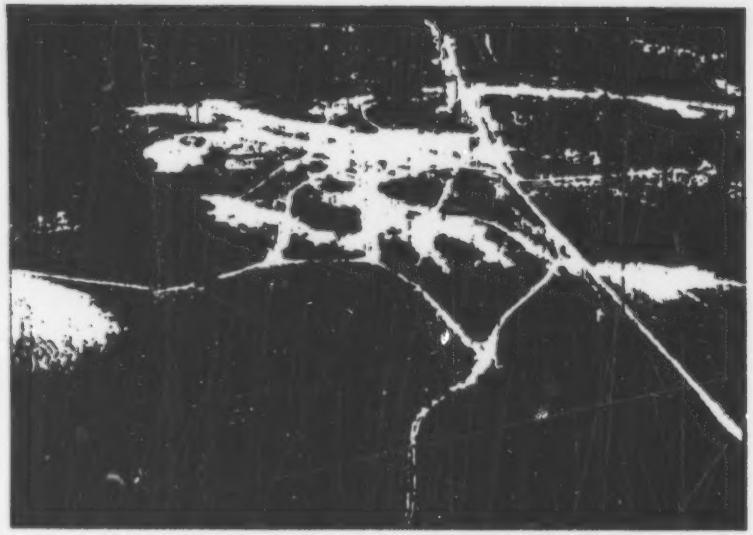

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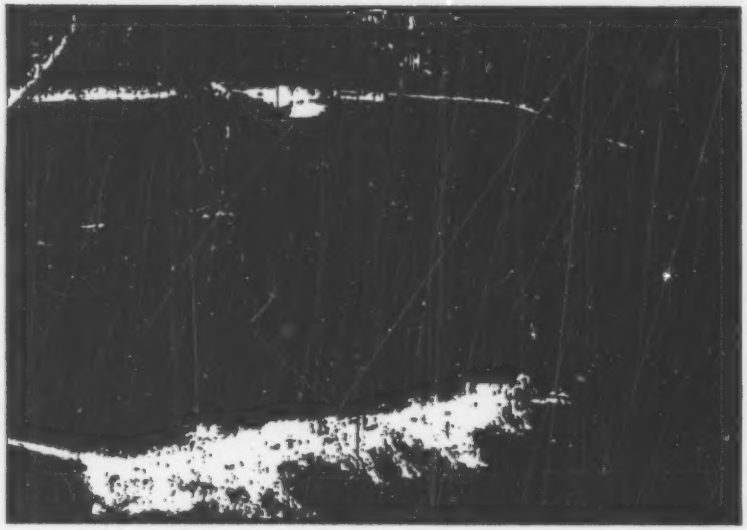

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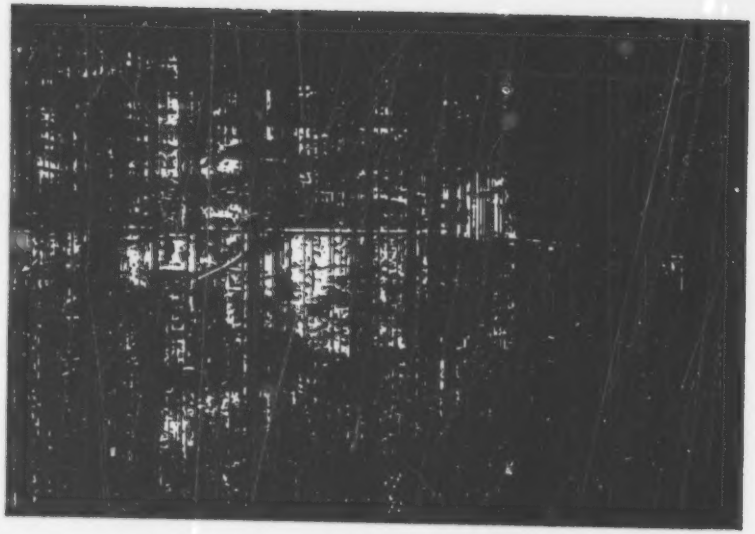

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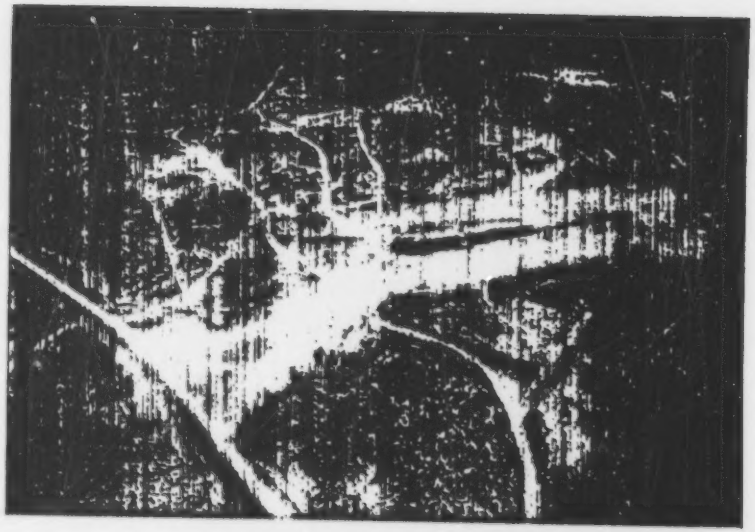

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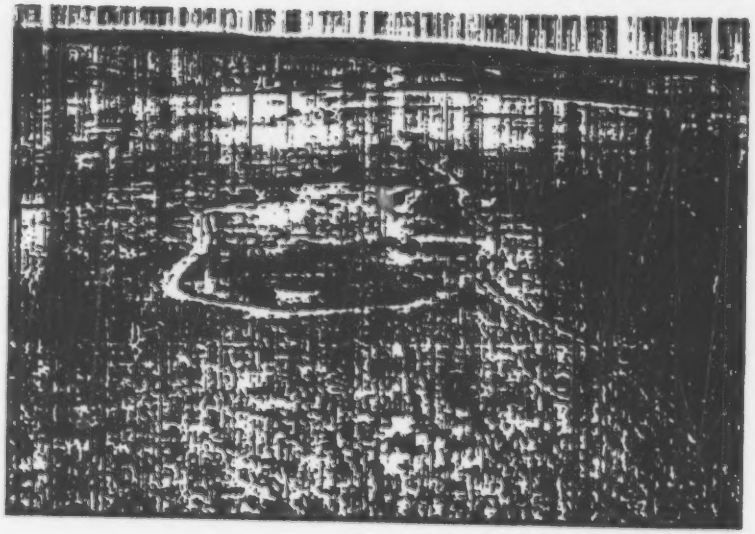

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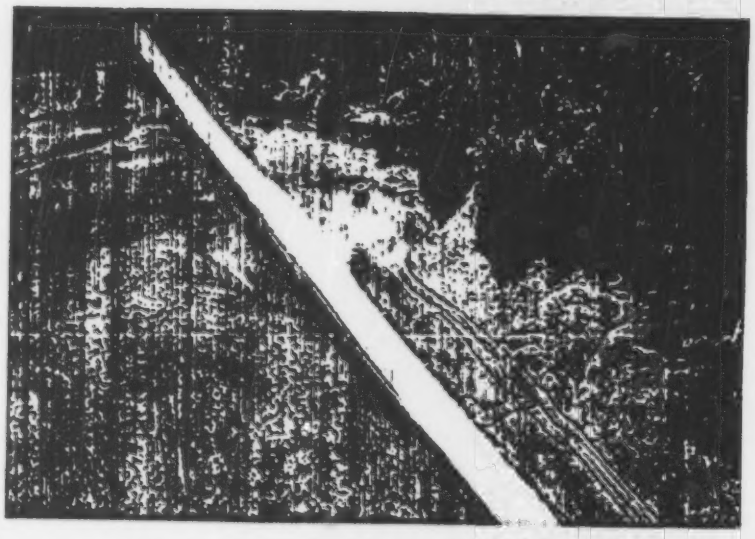

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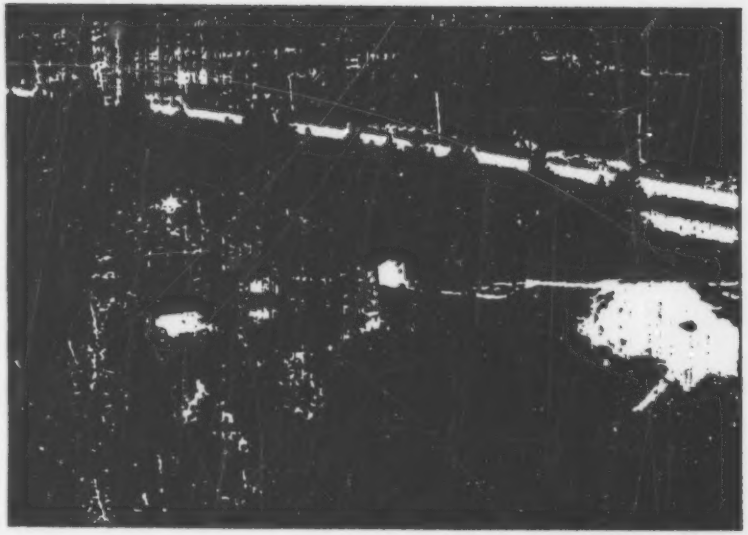

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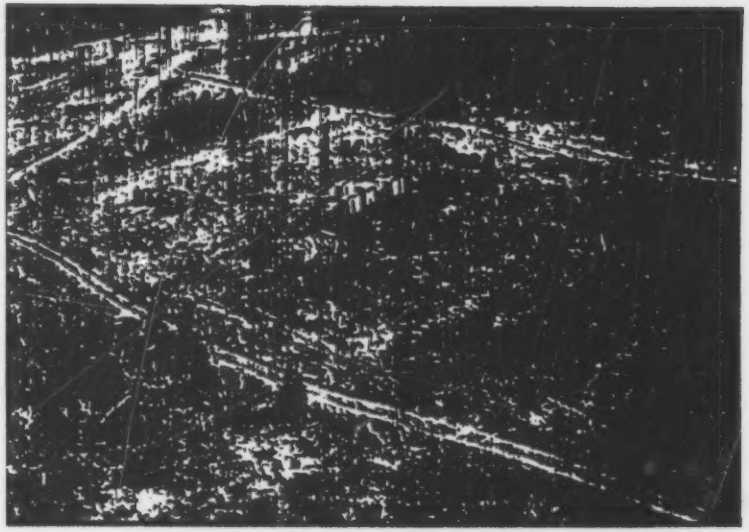

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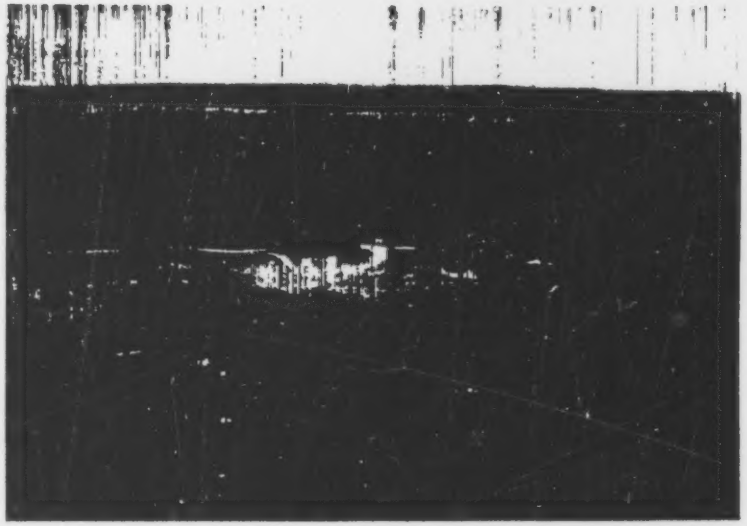

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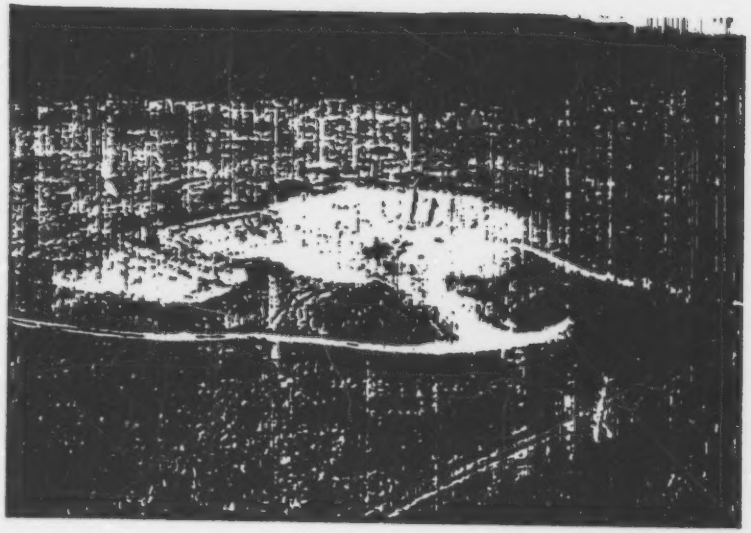

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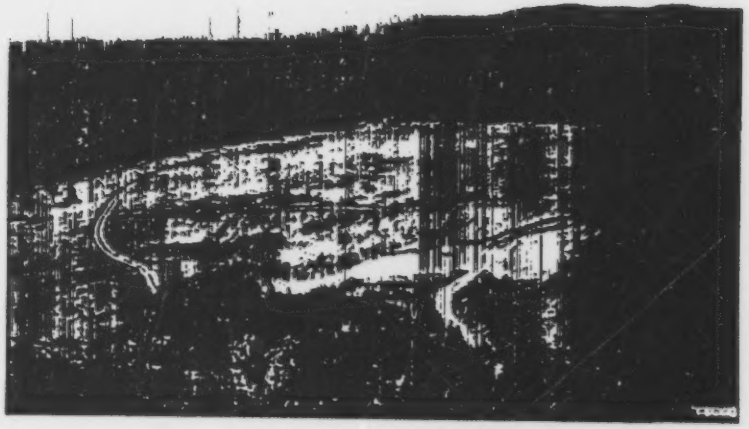

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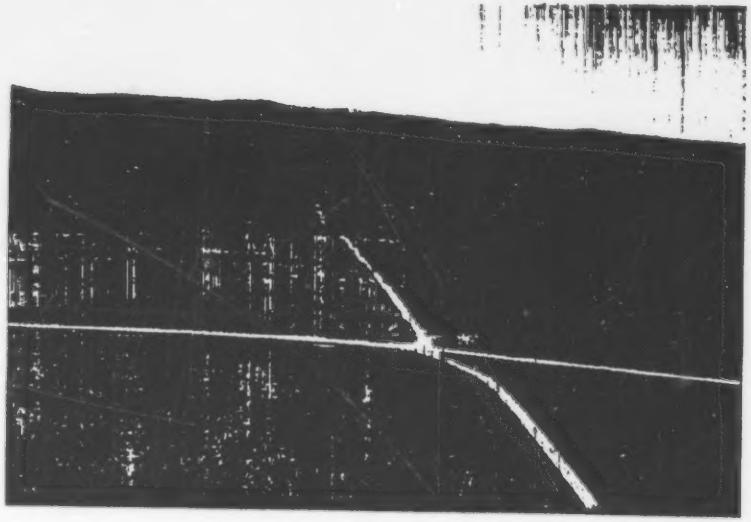

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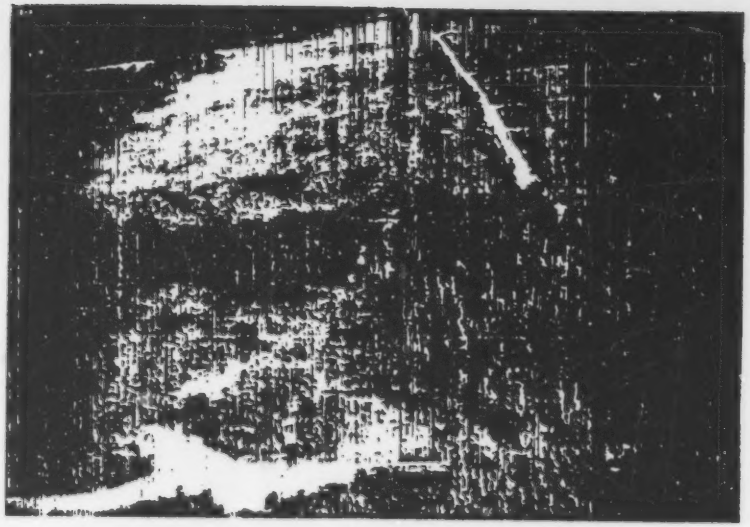

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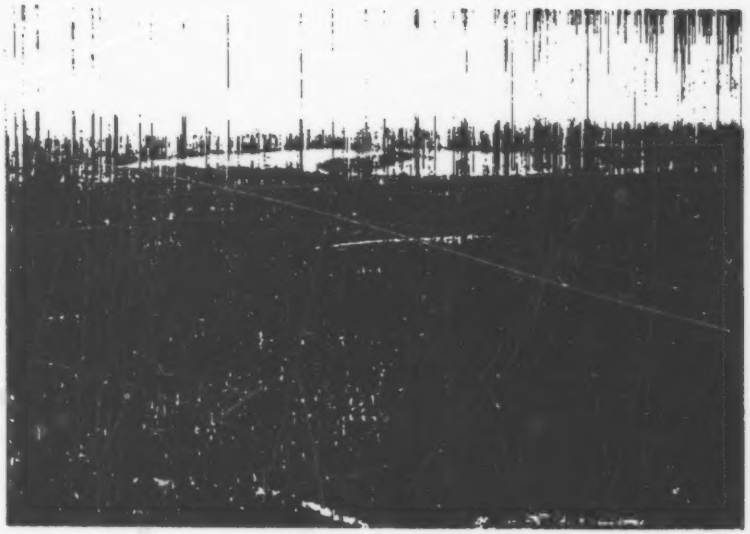

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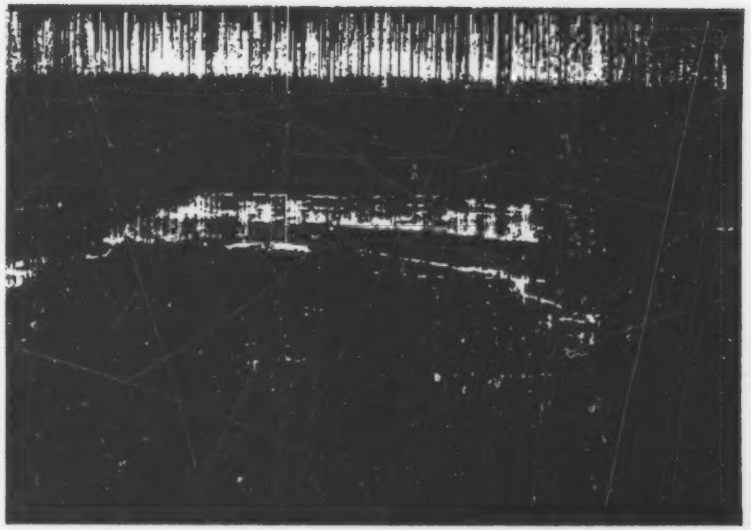

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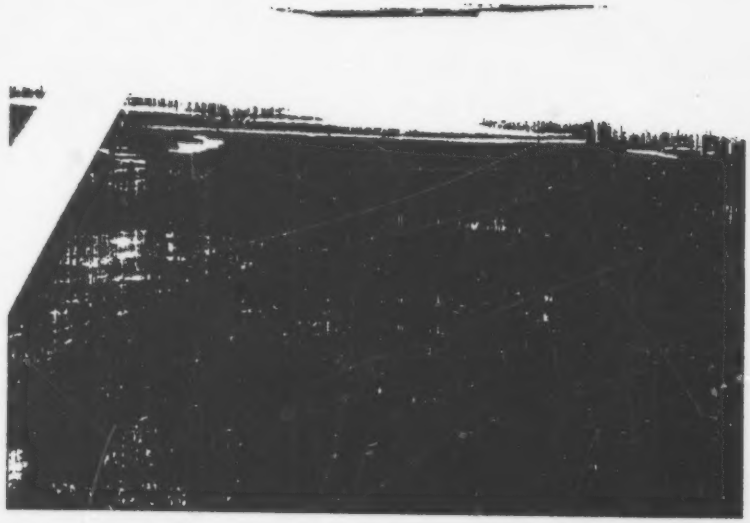

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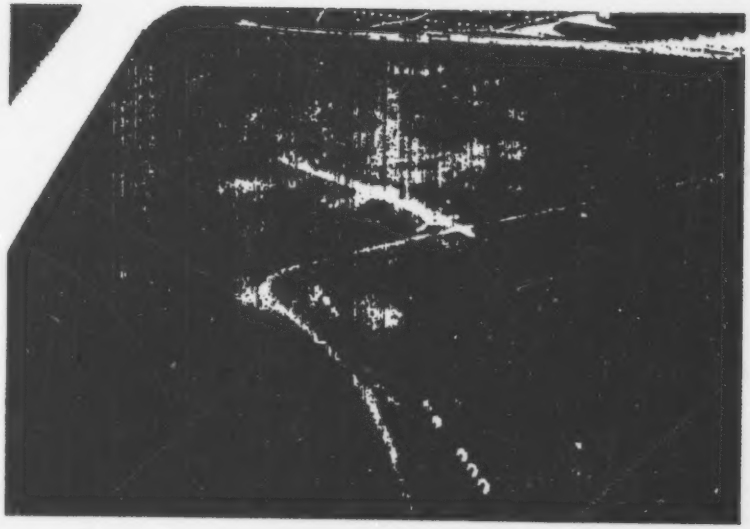

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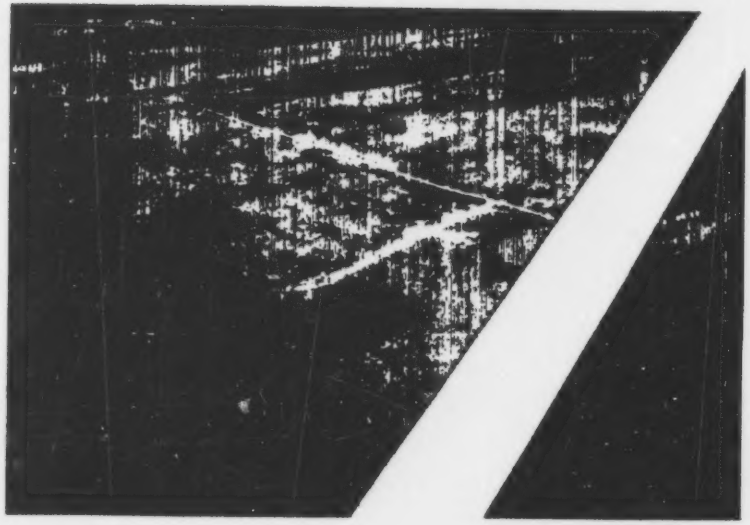

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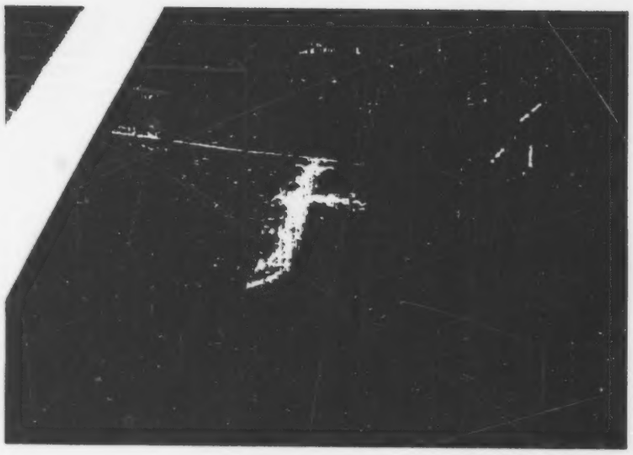

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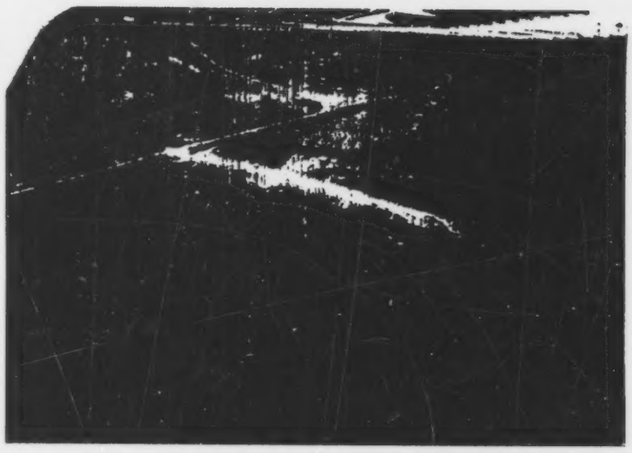

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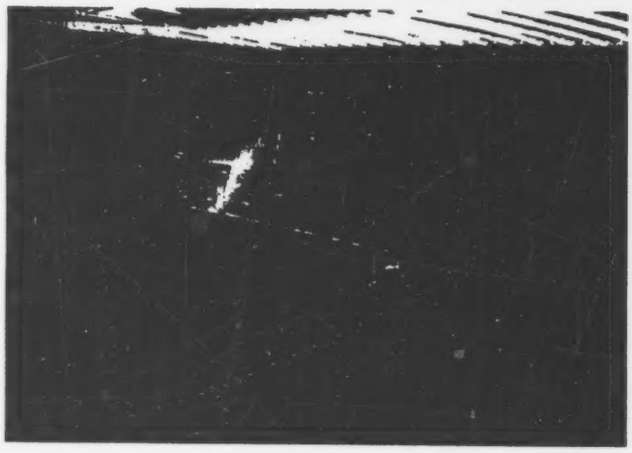

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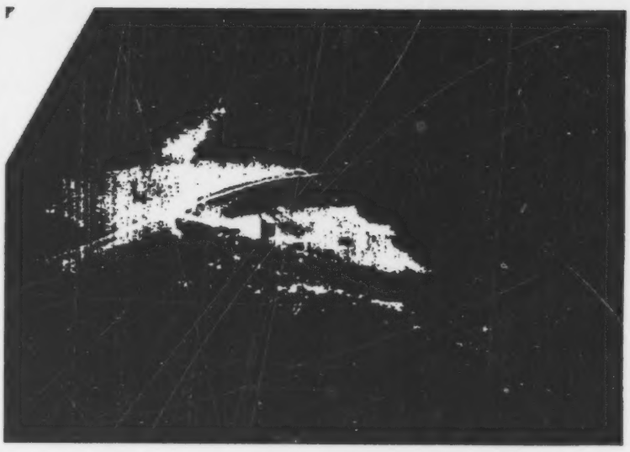

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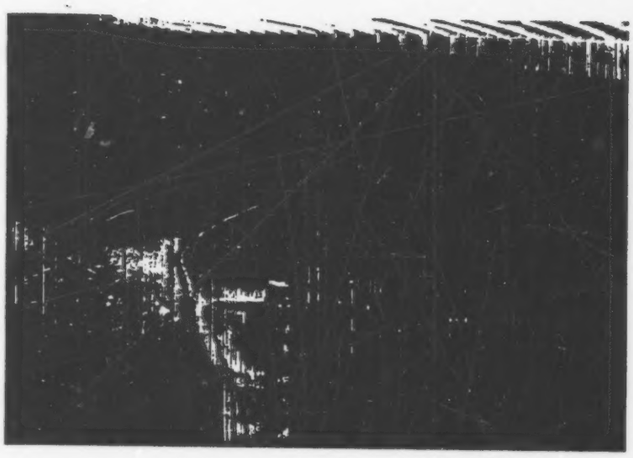

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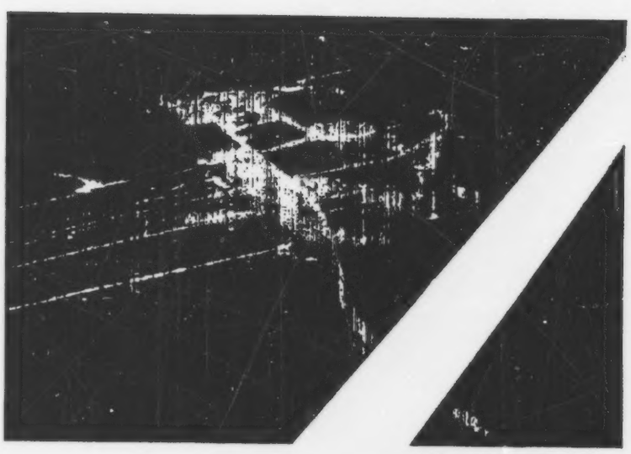

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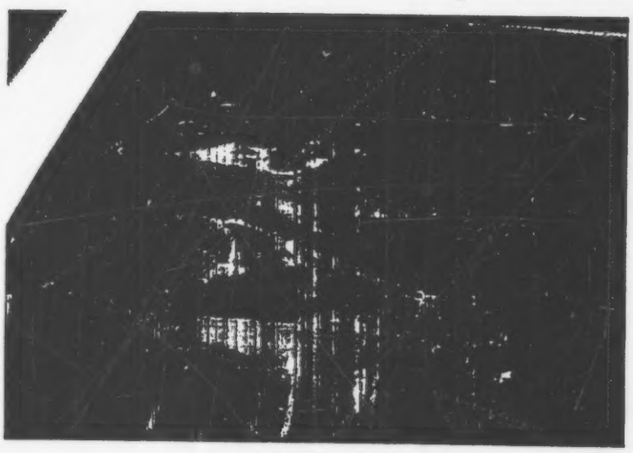

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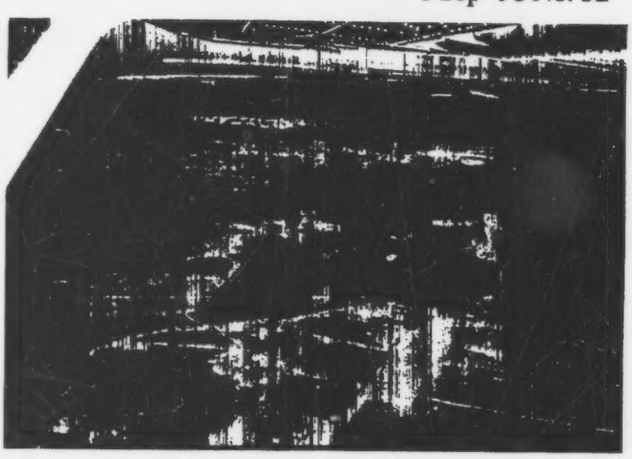

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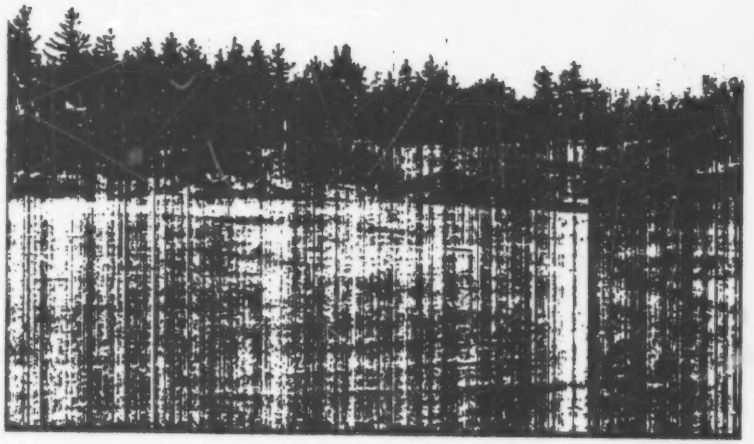

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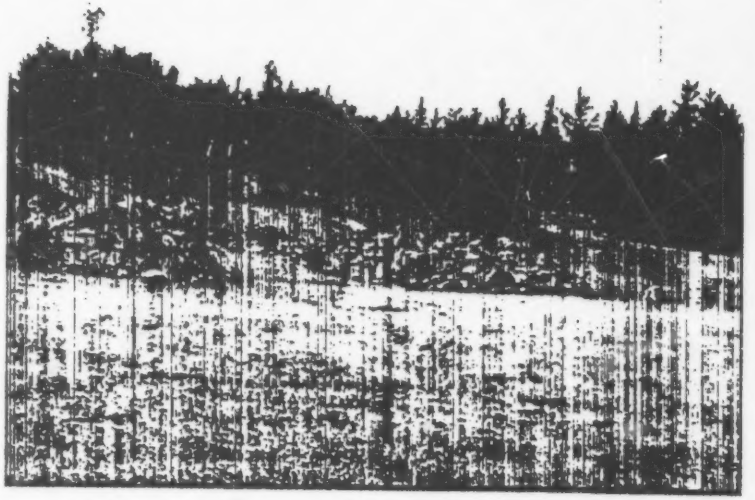

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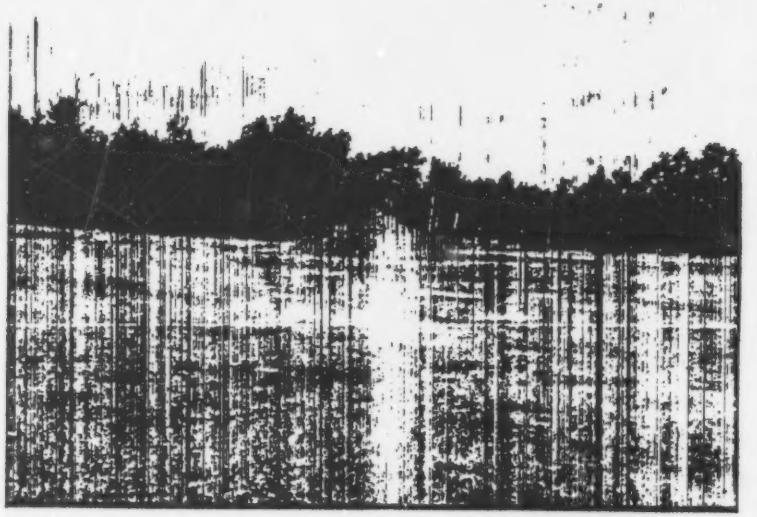

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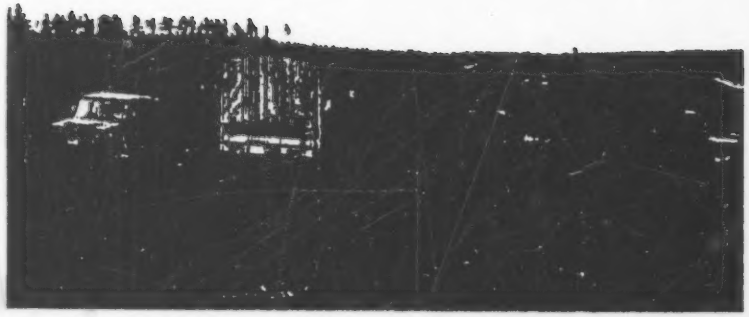

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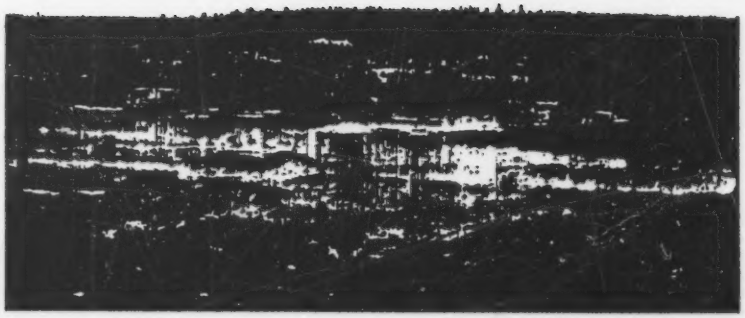

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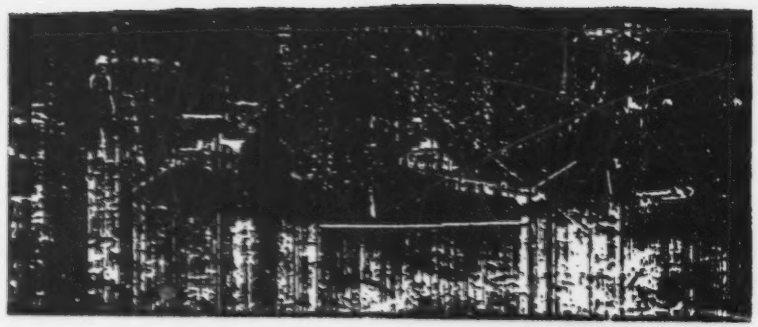
11 Dec '96 No. 4

11 Dec '96 No. 5

11 Dec '96 No. 6



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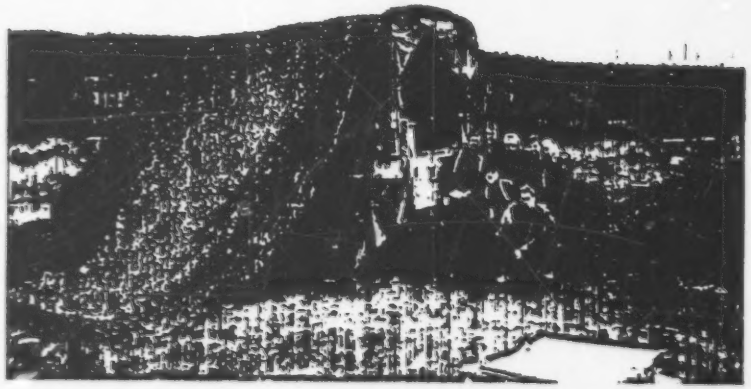

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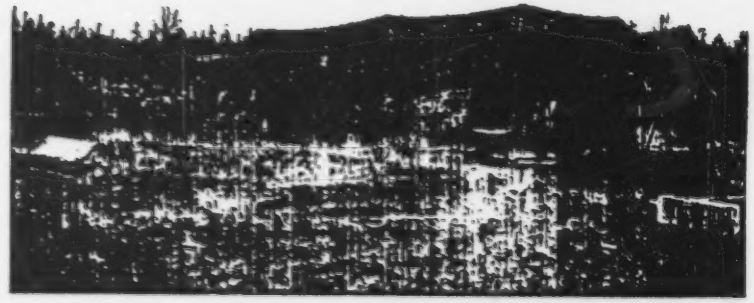

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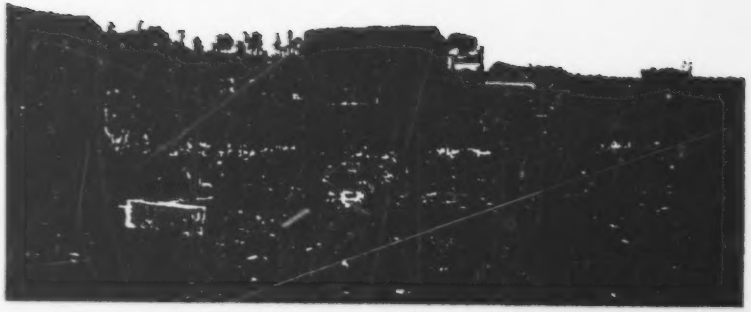

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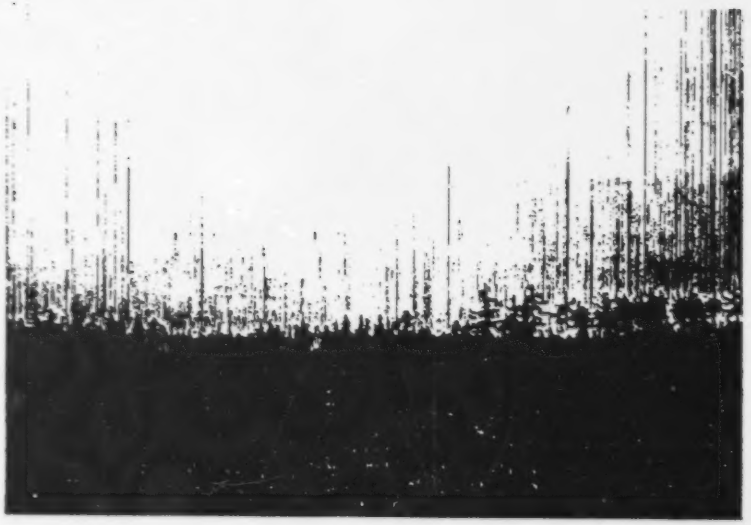

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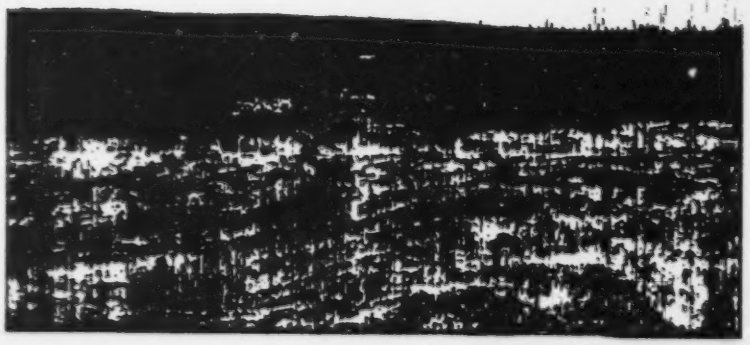
11 Dec '96 No. 15



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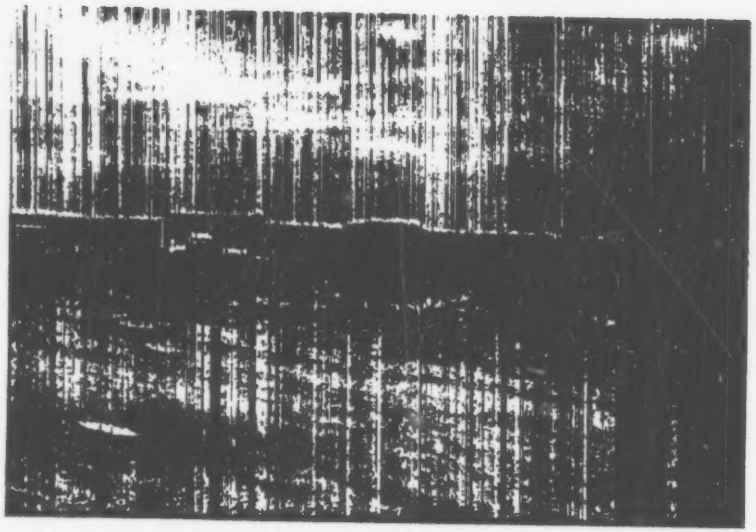

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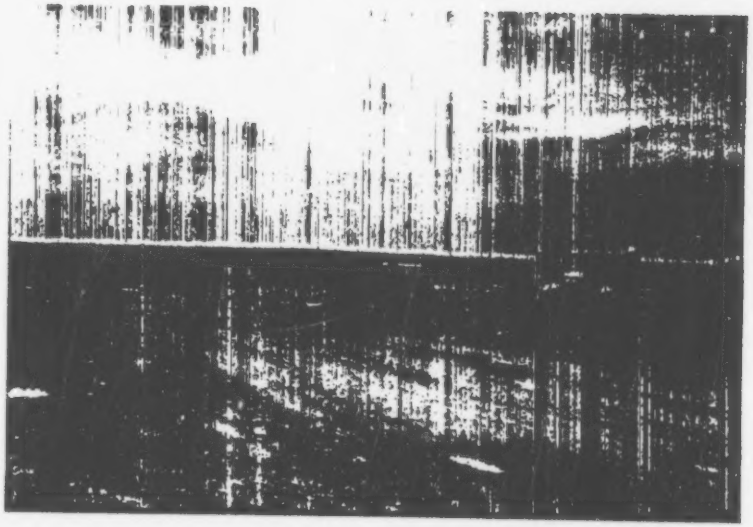

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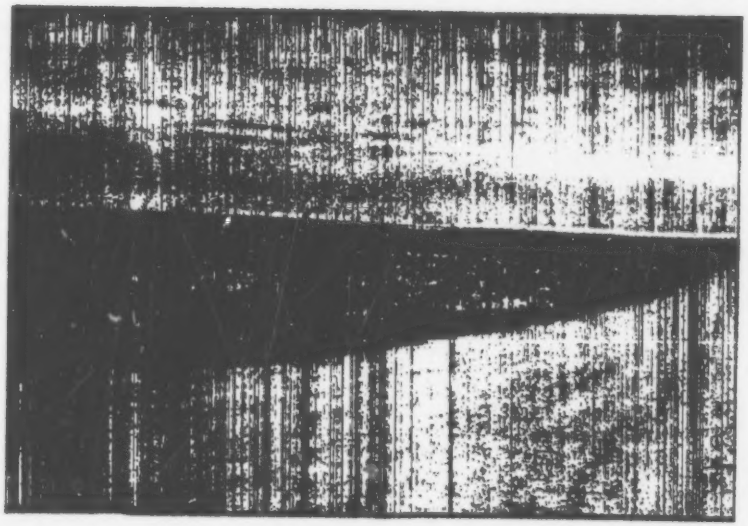

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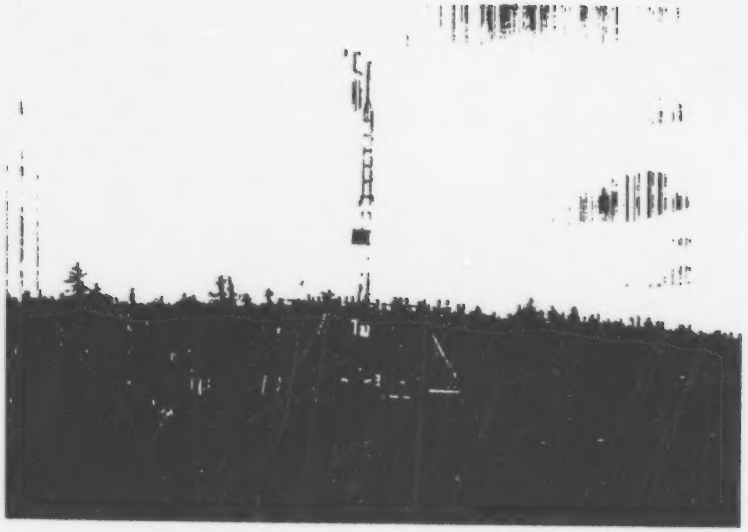

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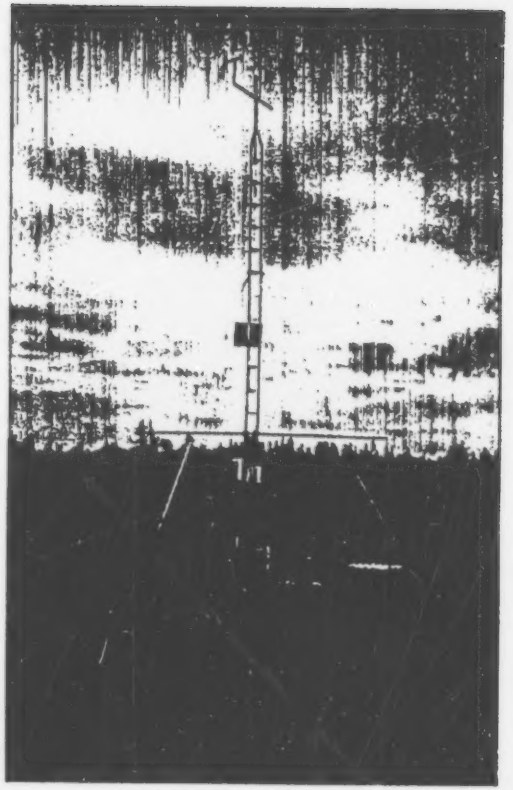

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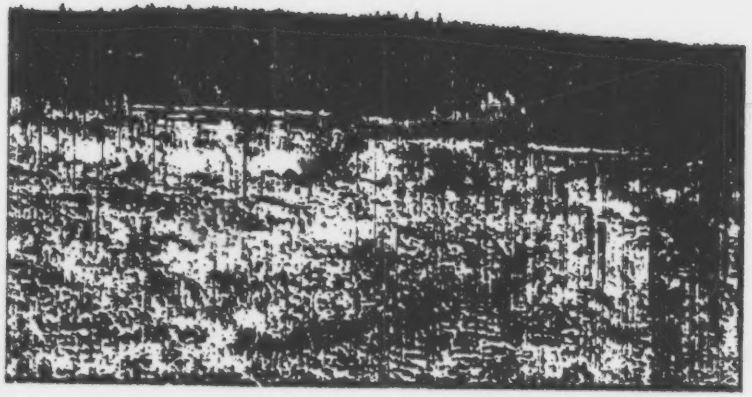

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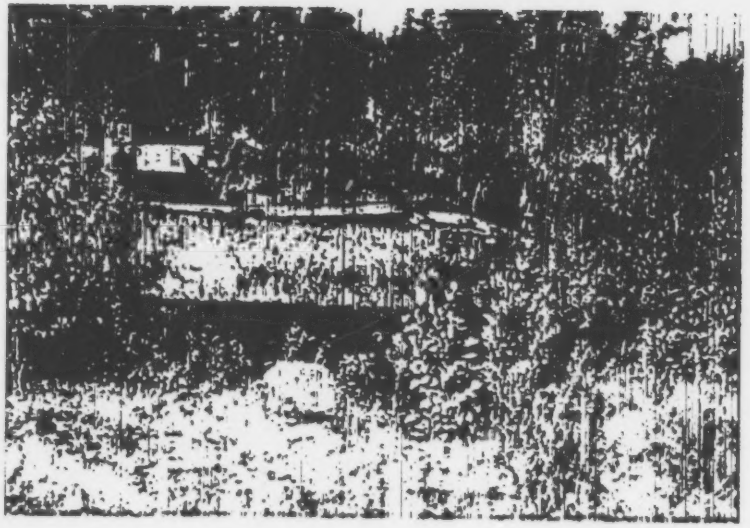

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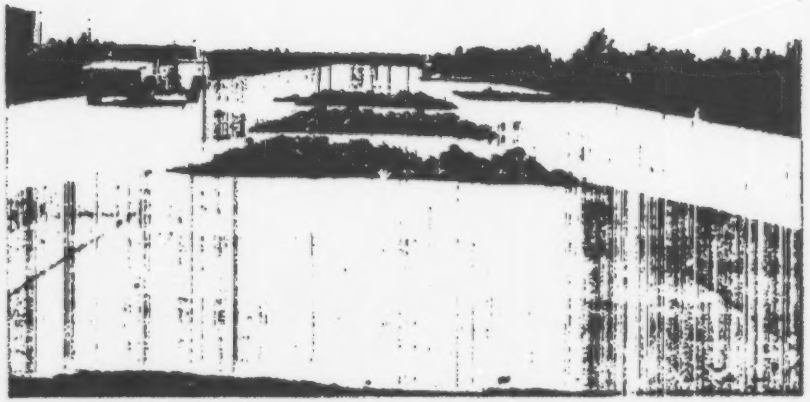
97_1697



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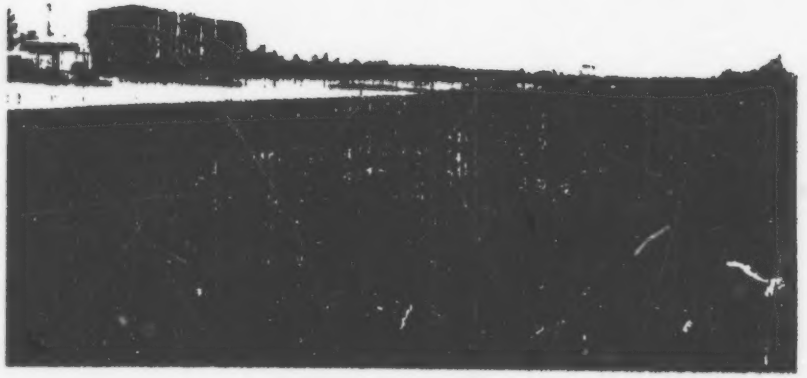

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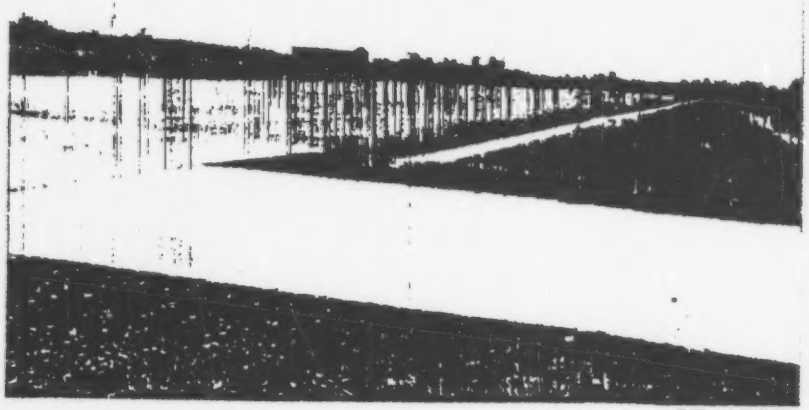

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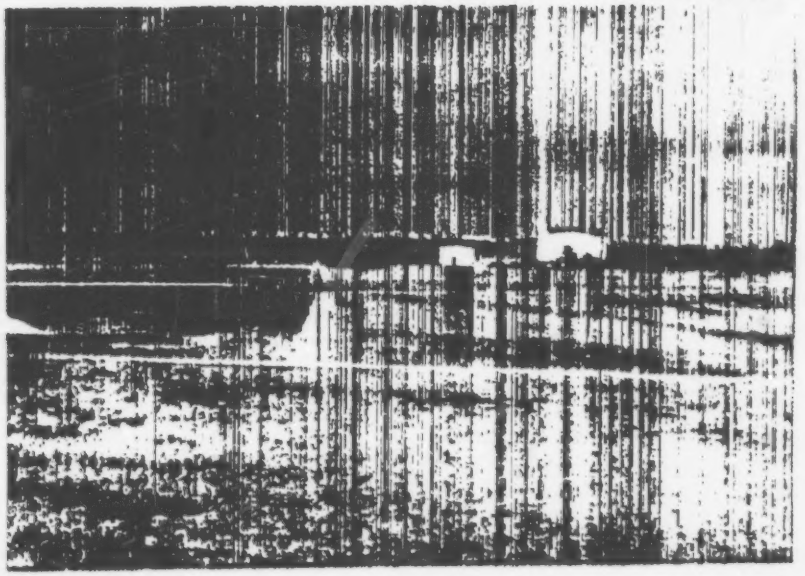

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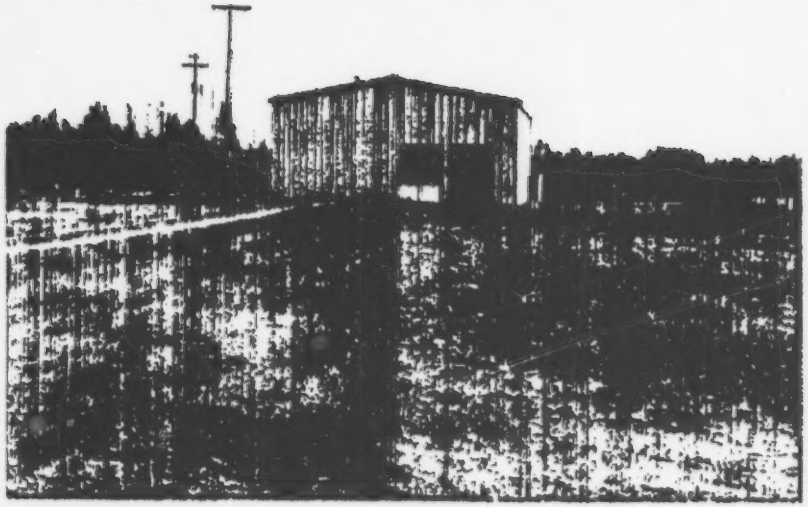

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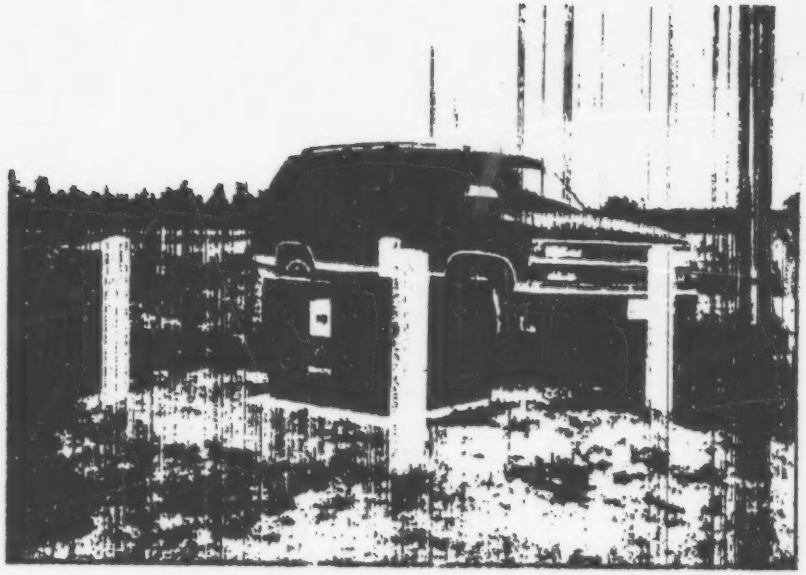

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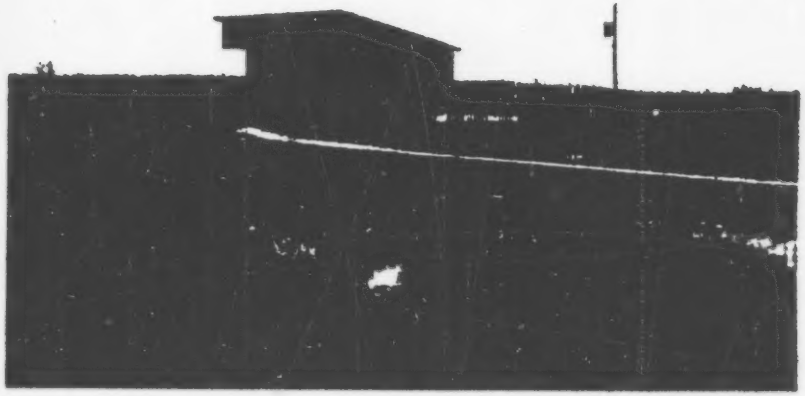

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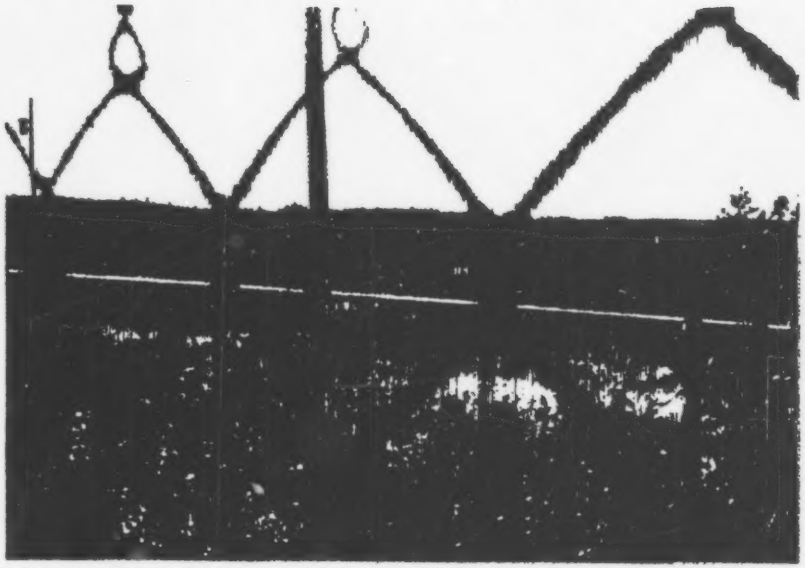

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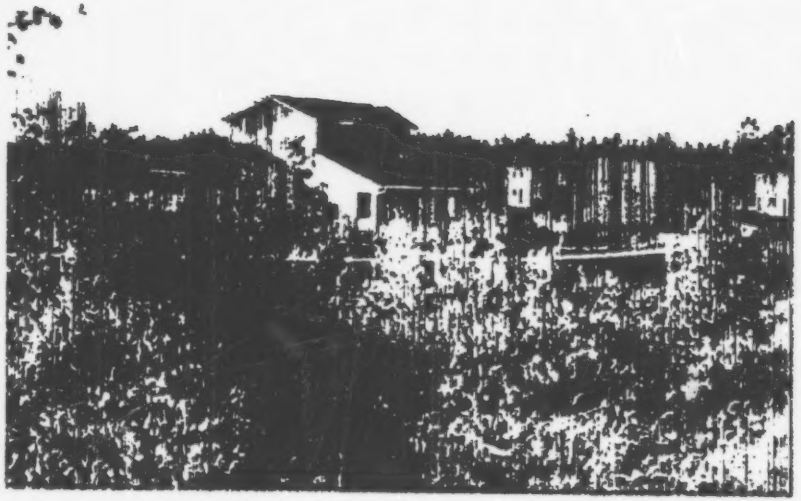

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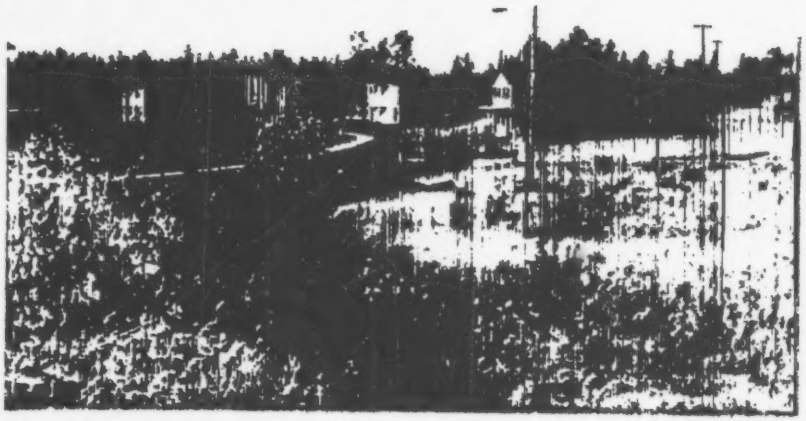

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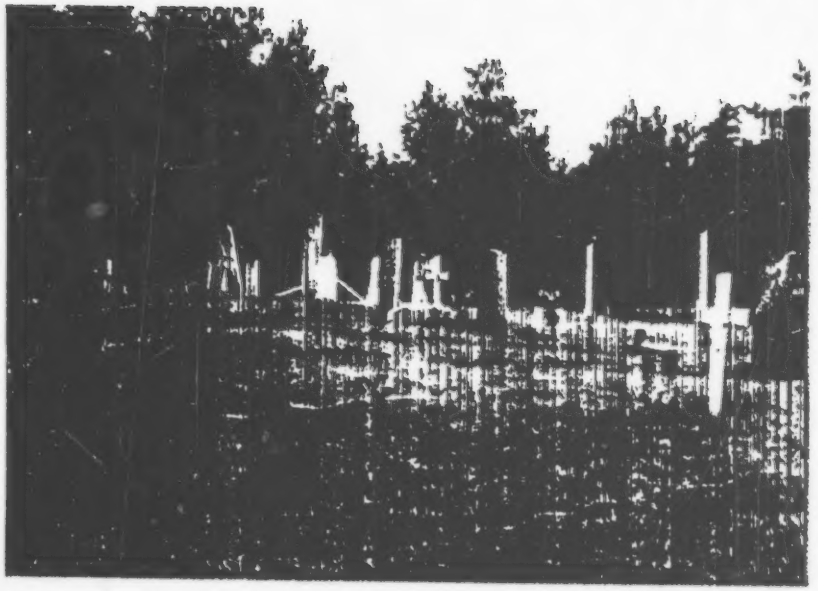

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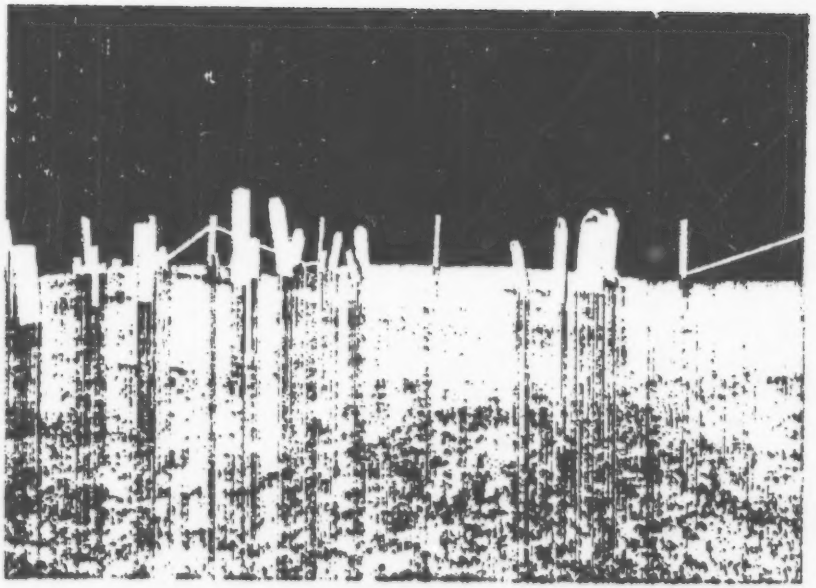

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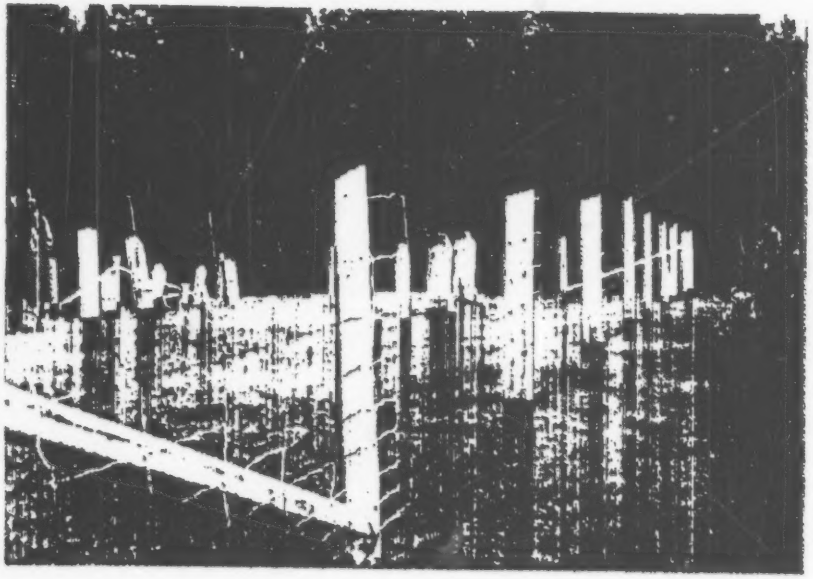

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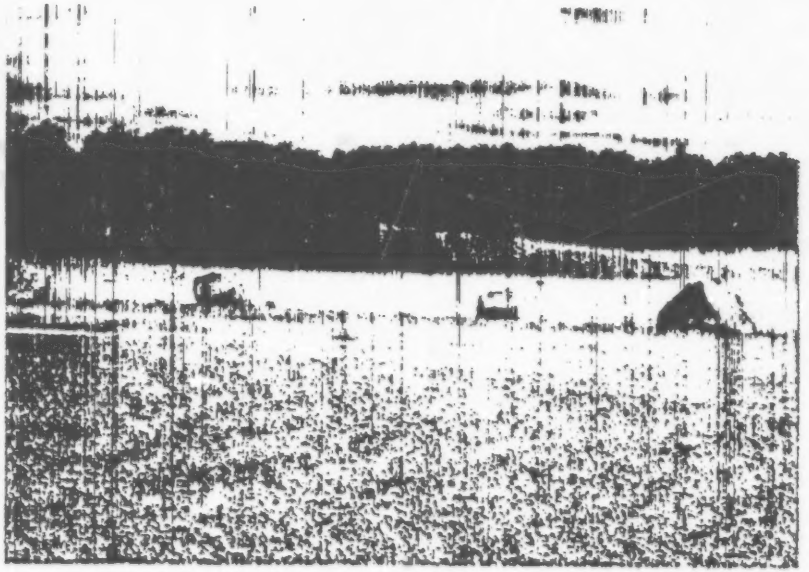

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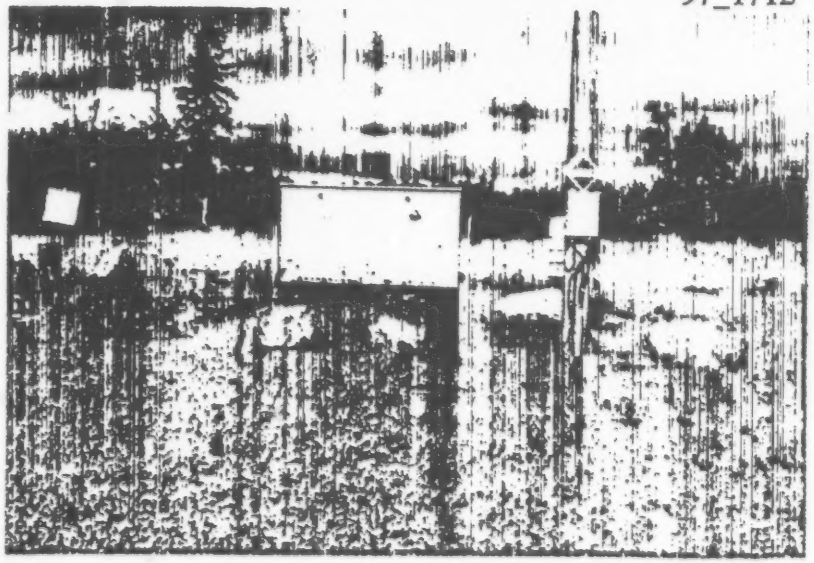

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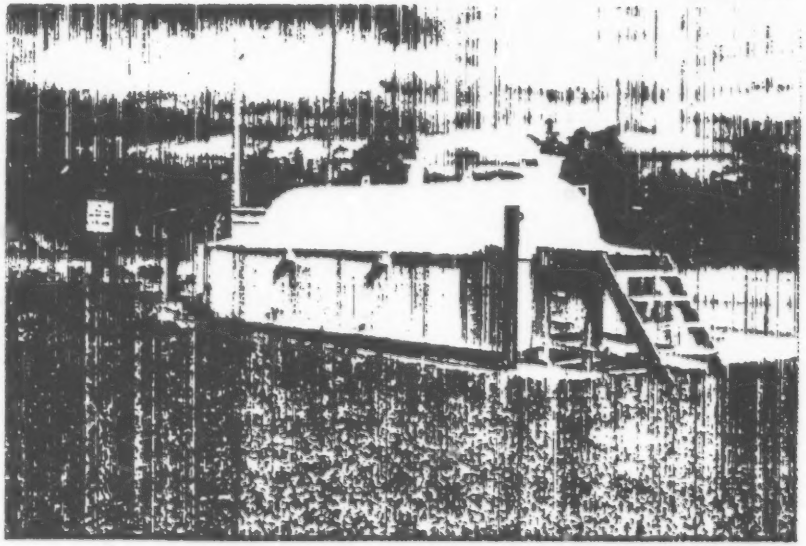

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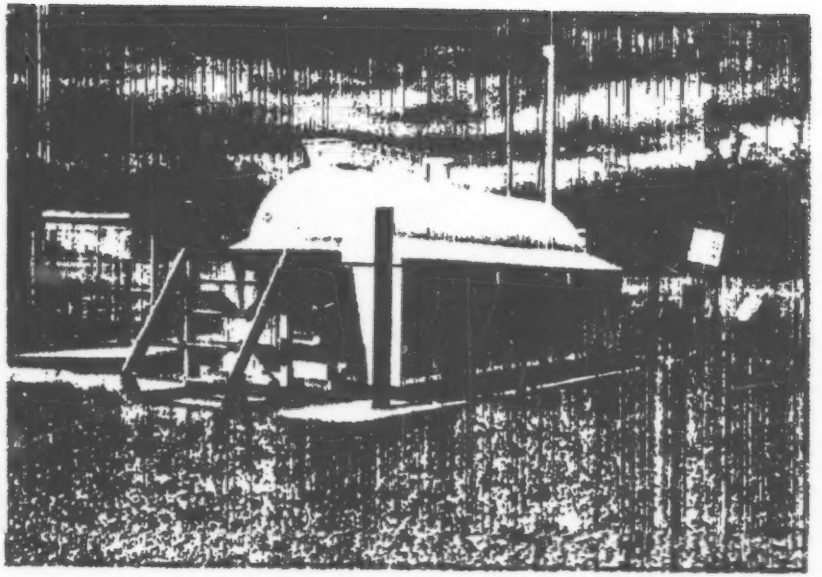

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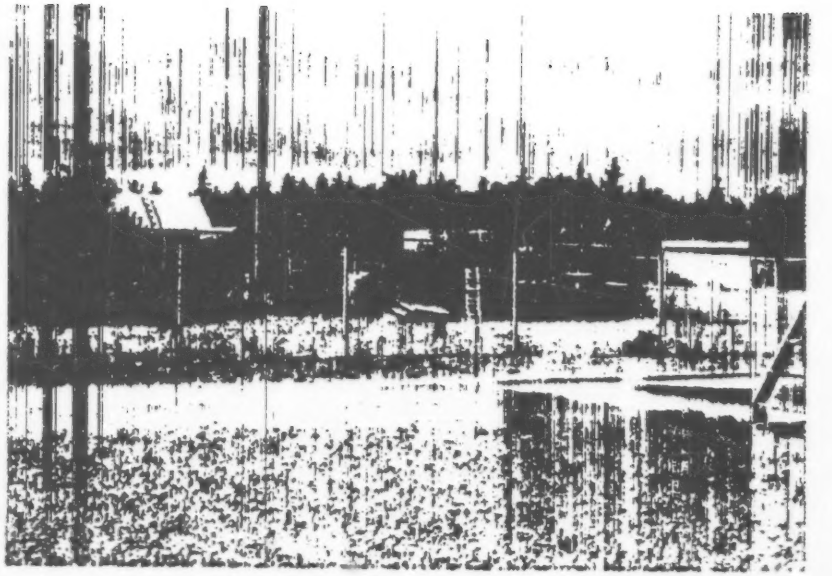

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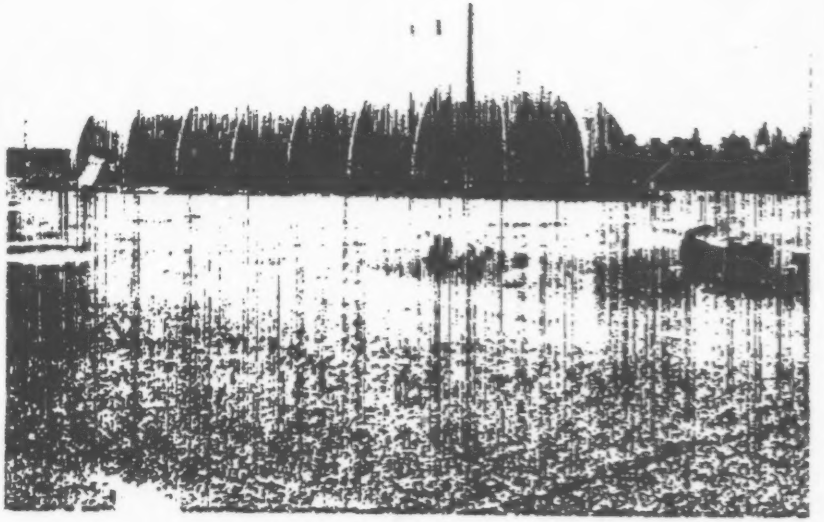

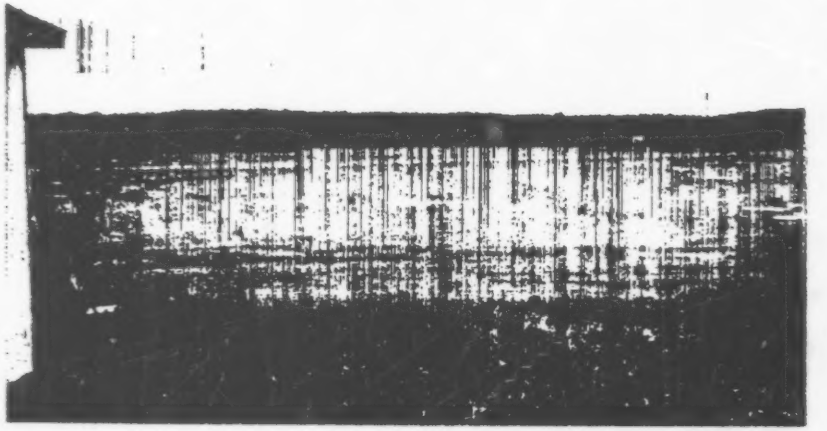

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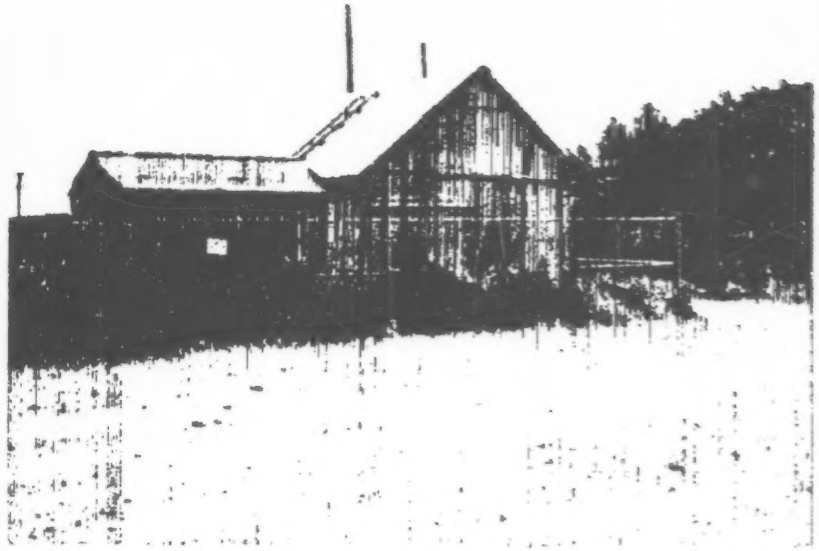

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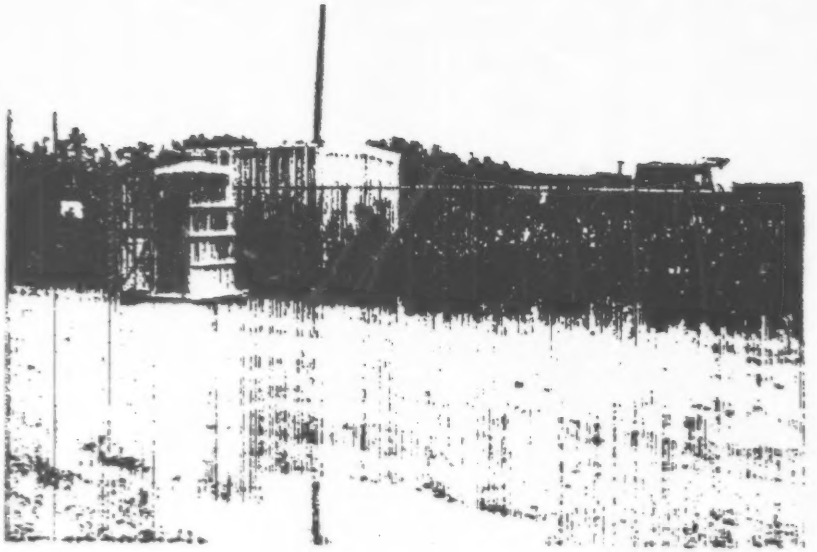

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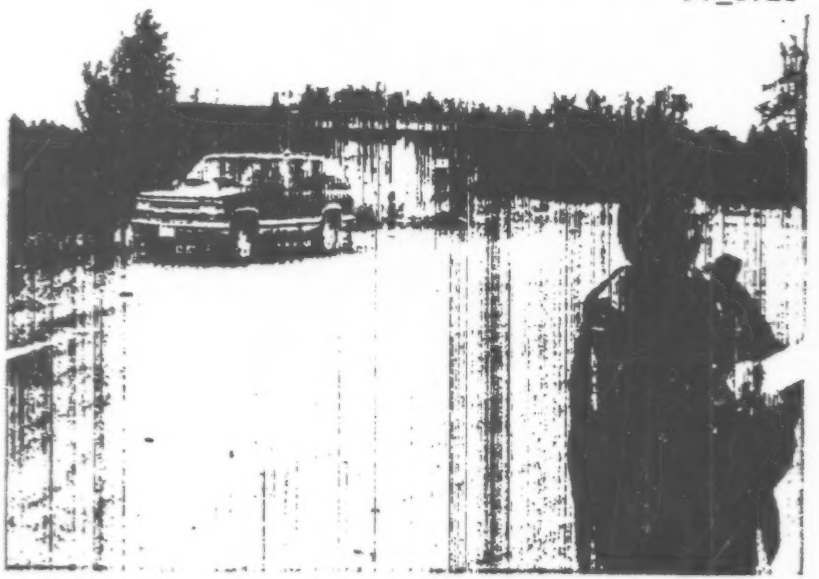

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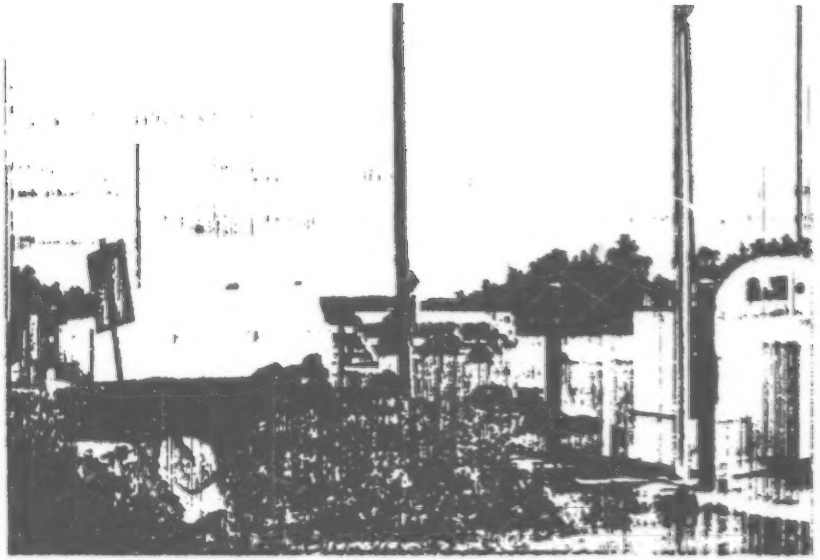

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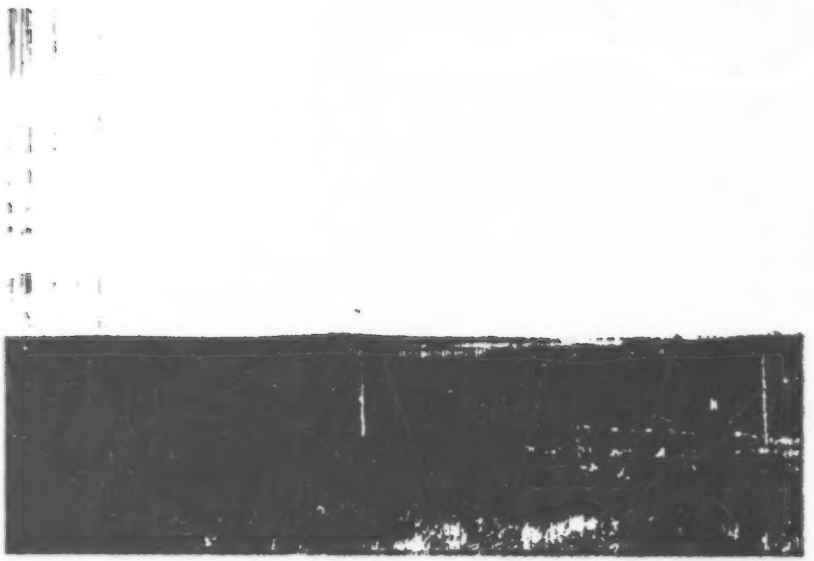

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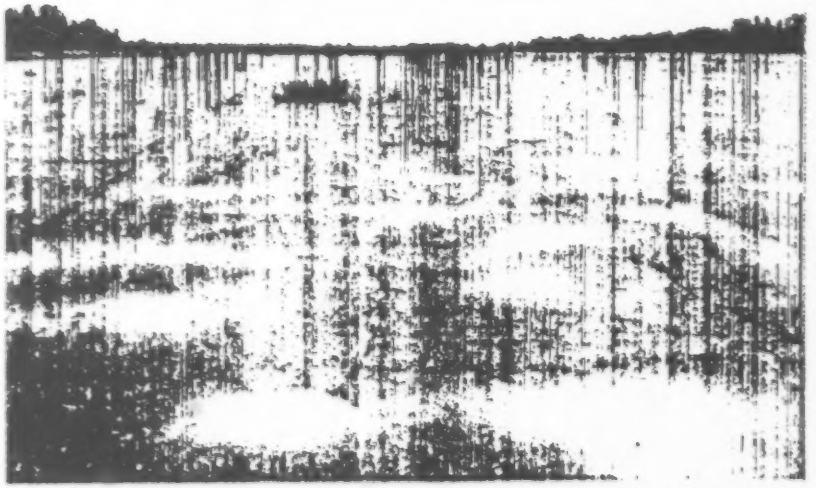

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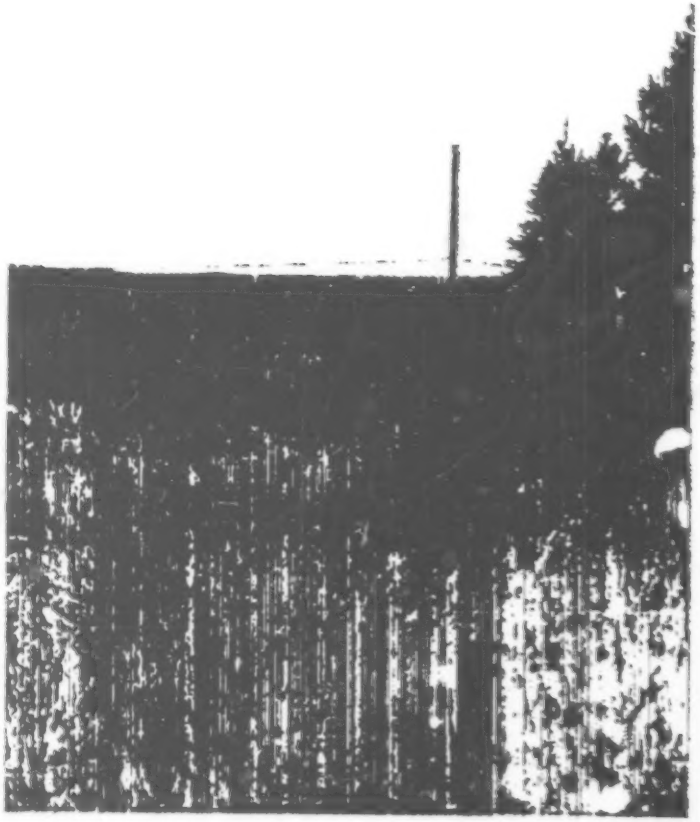

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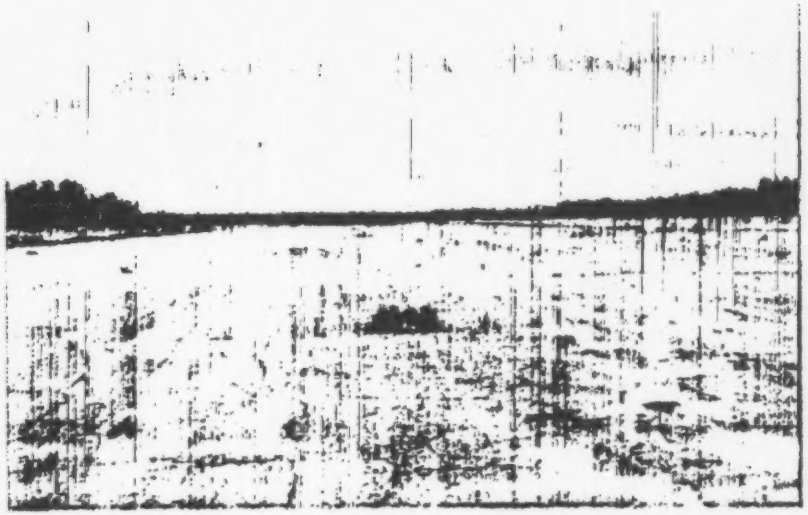

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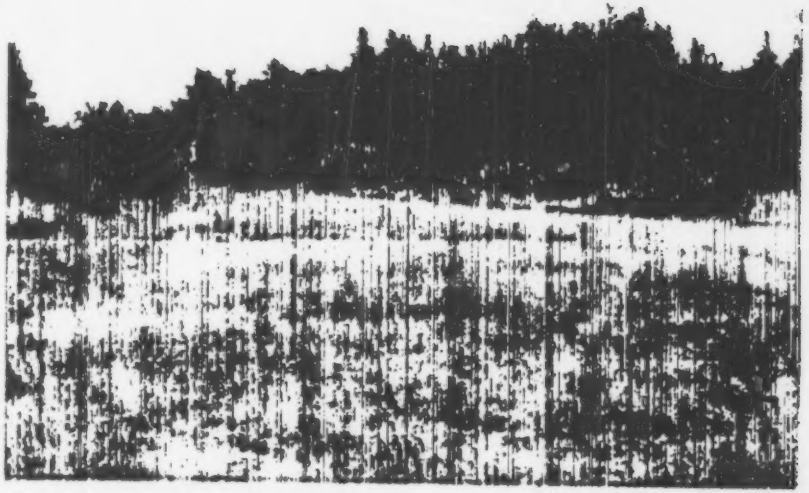

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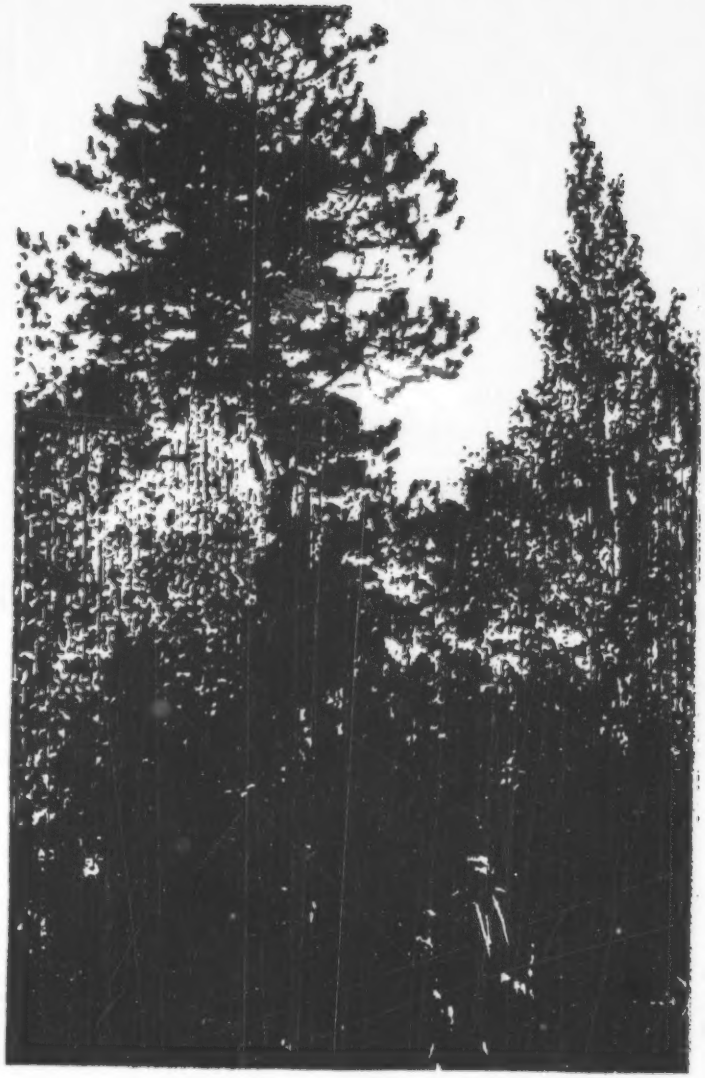

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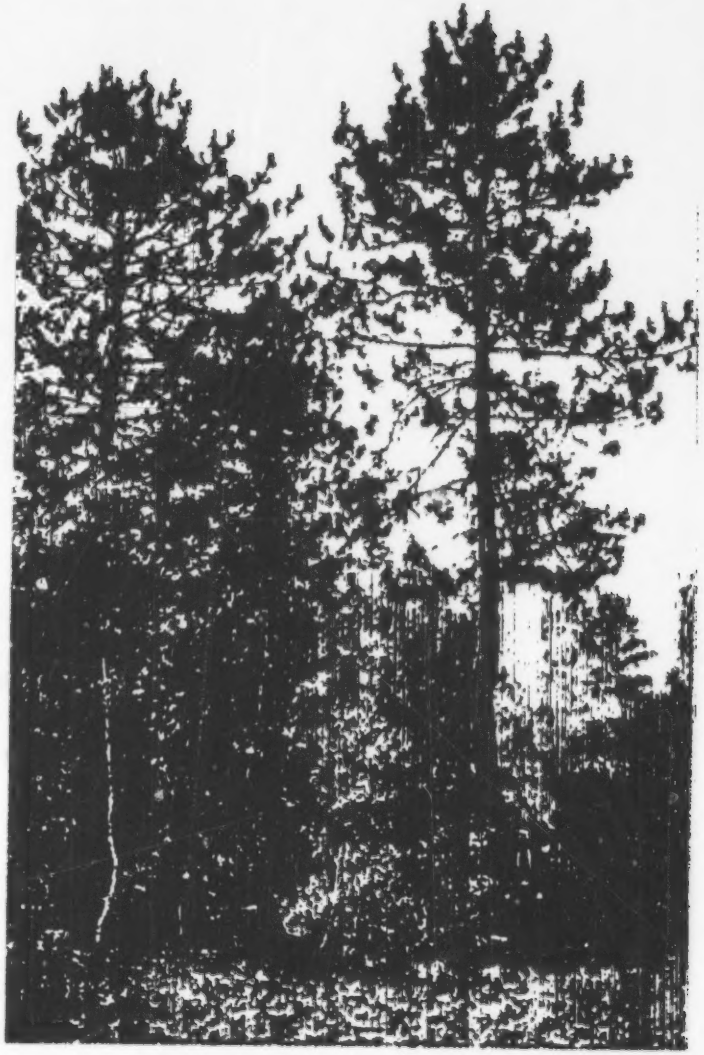

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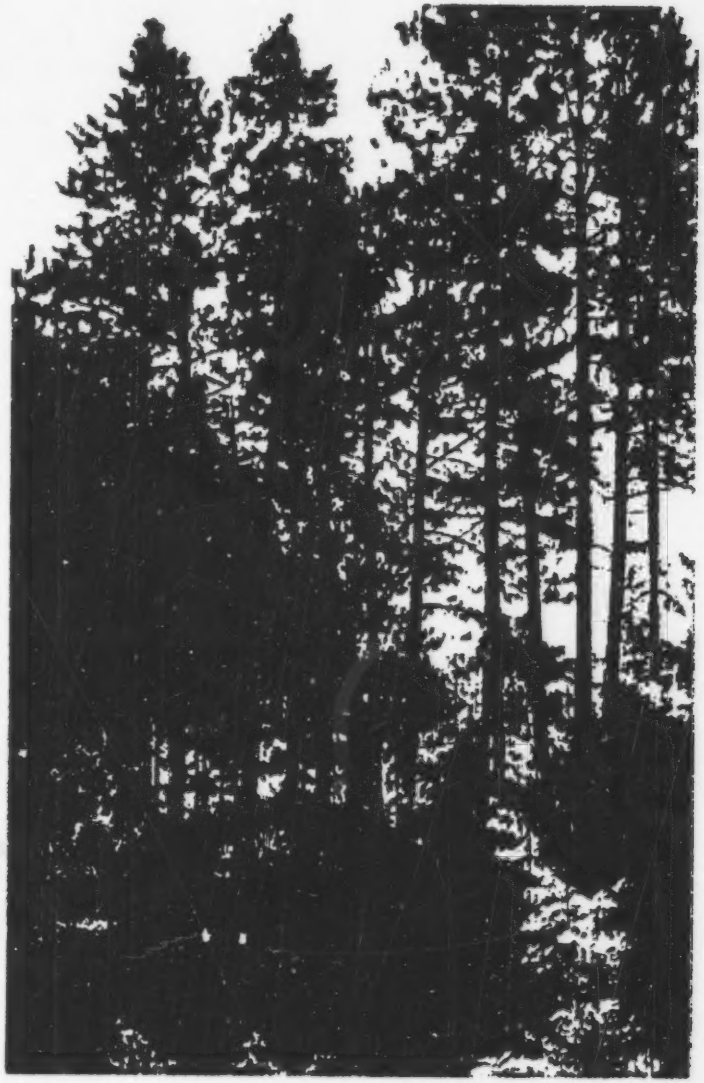

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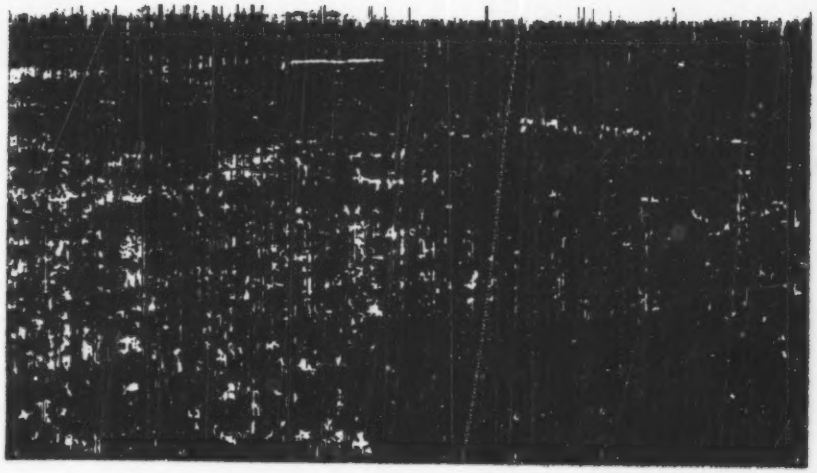

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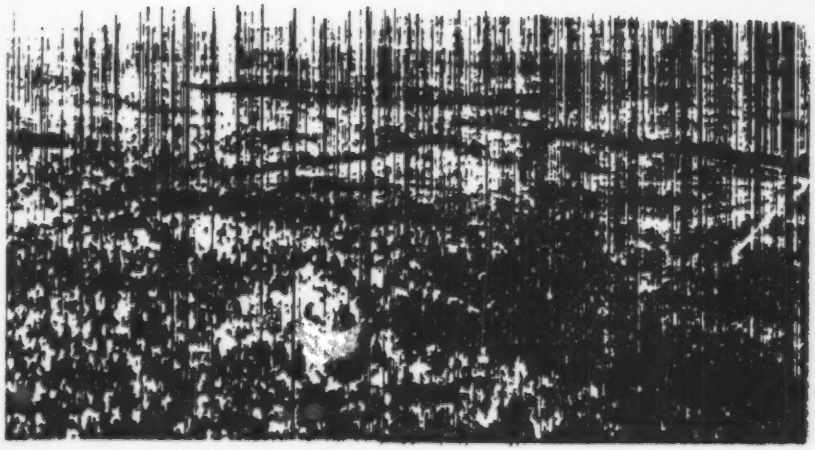

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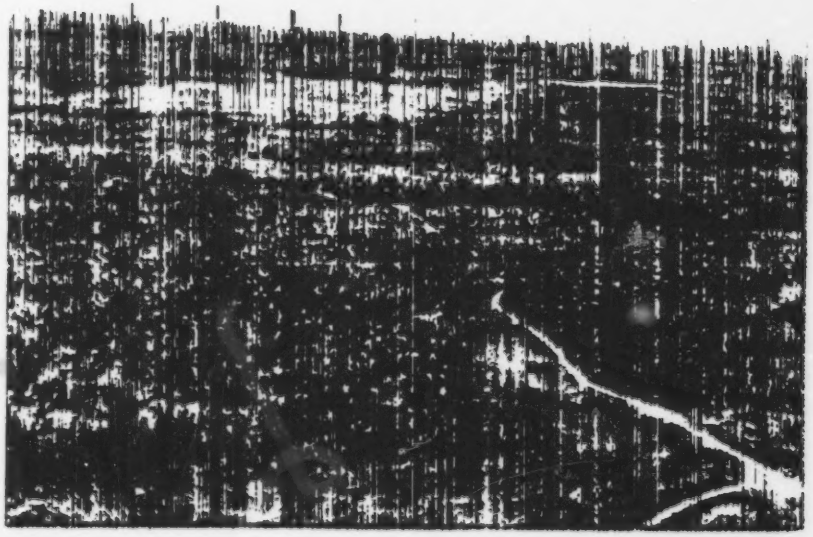

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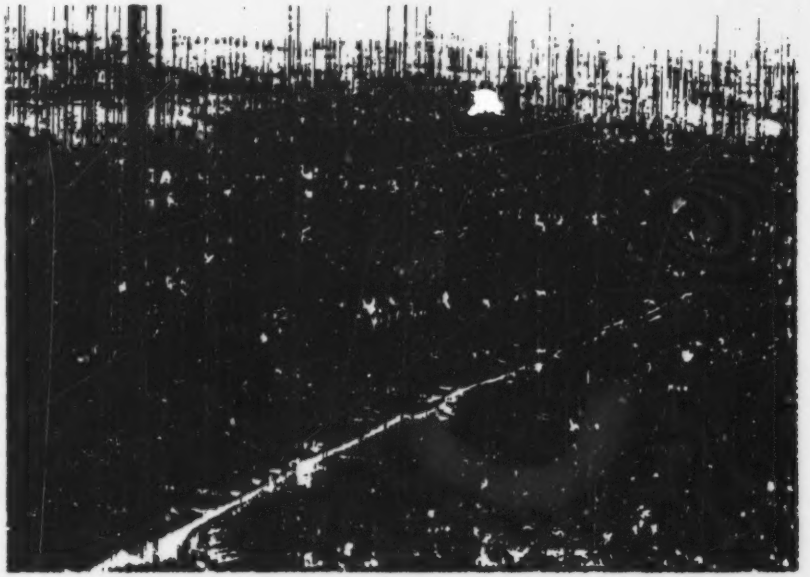

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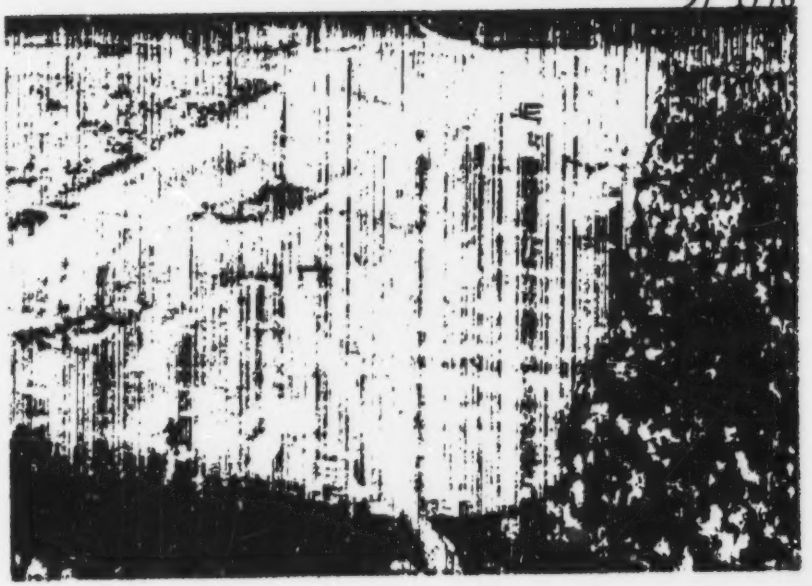

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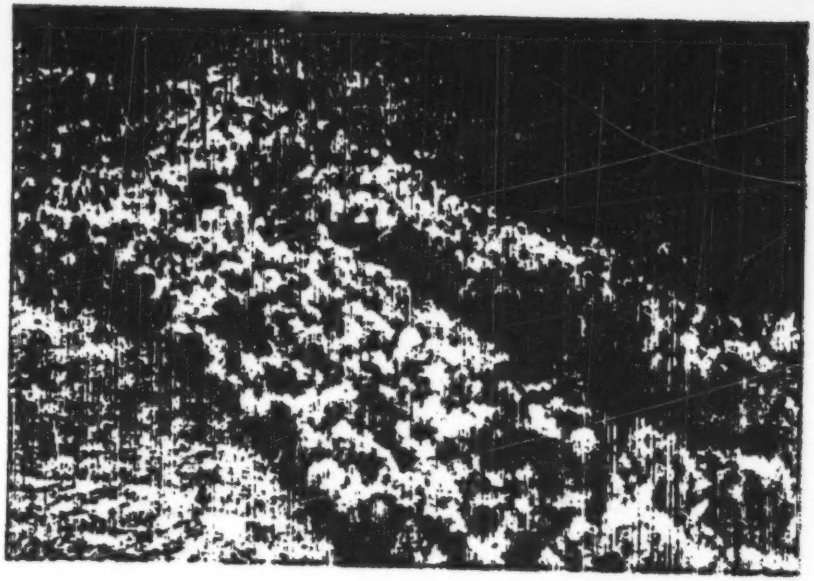

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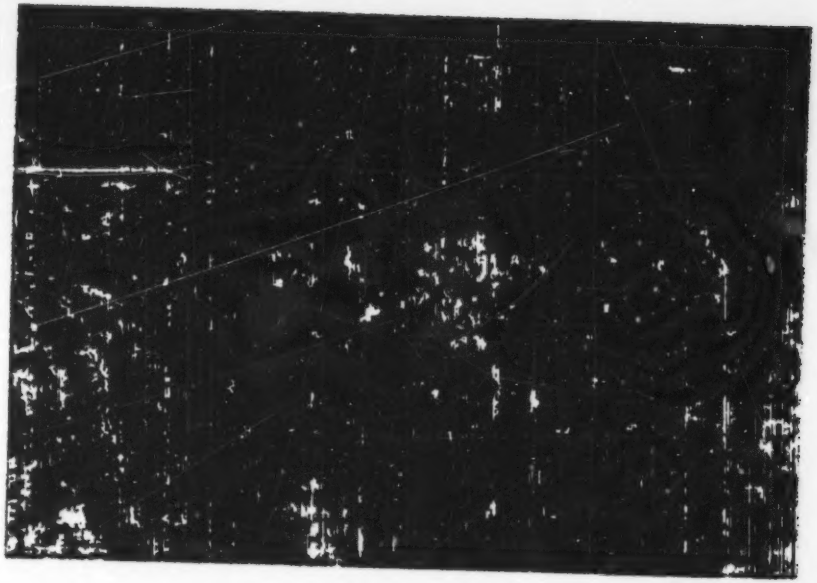

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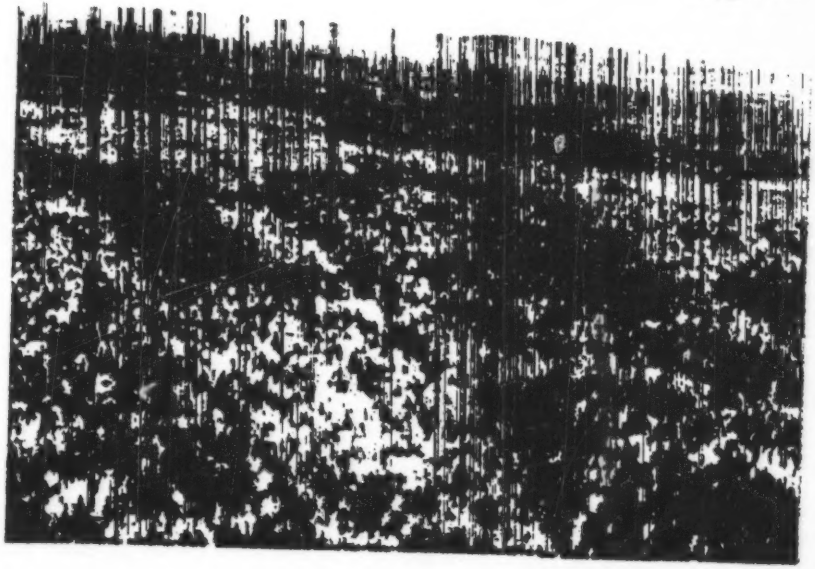

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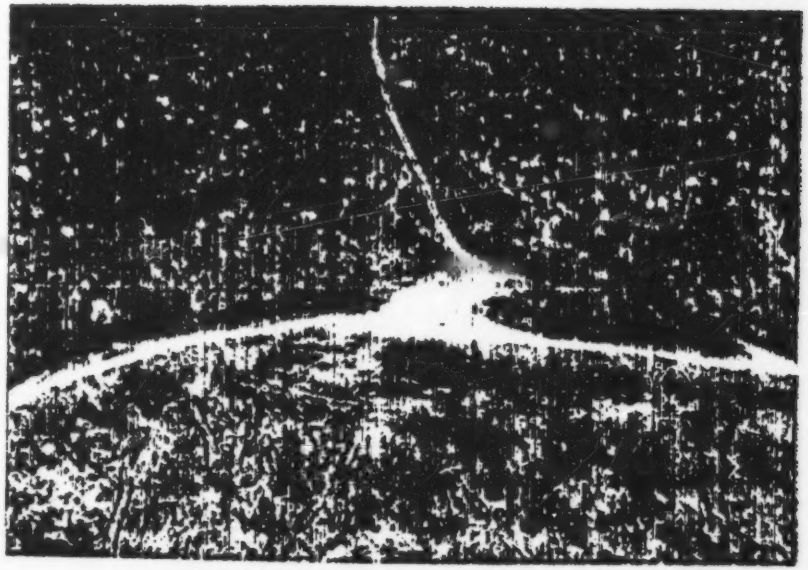

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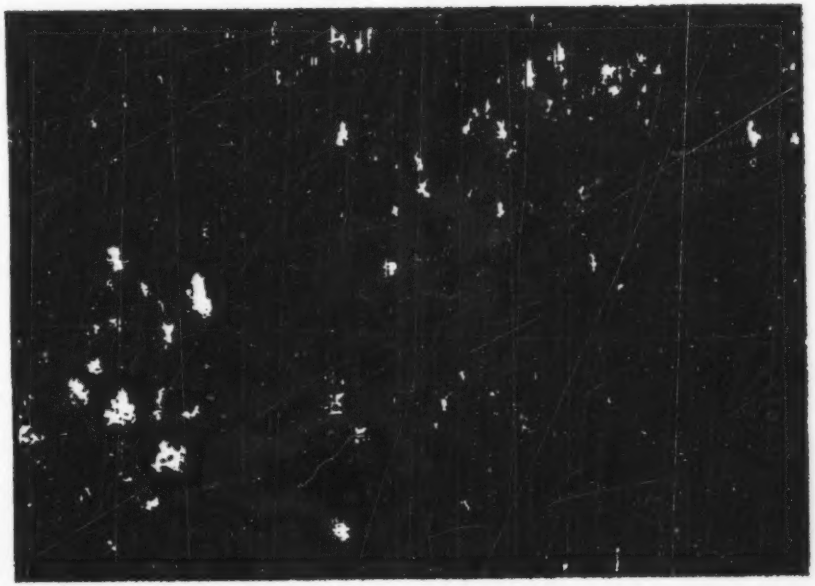

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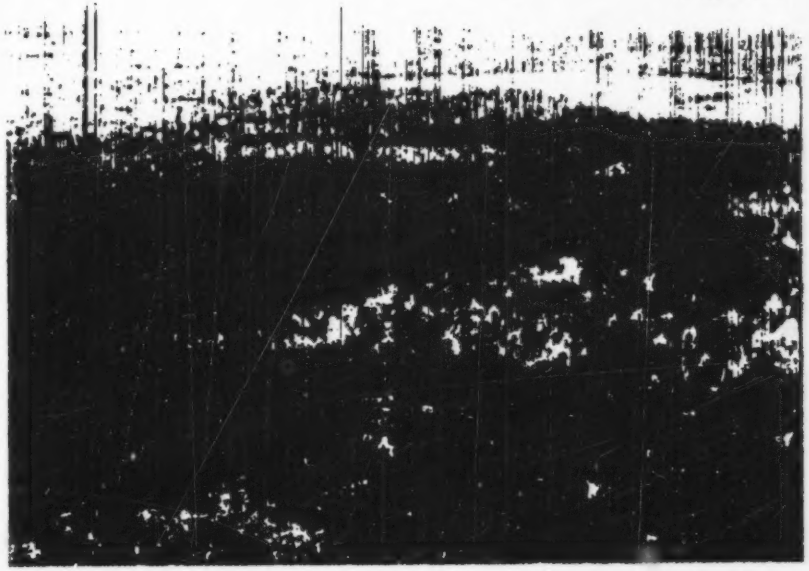

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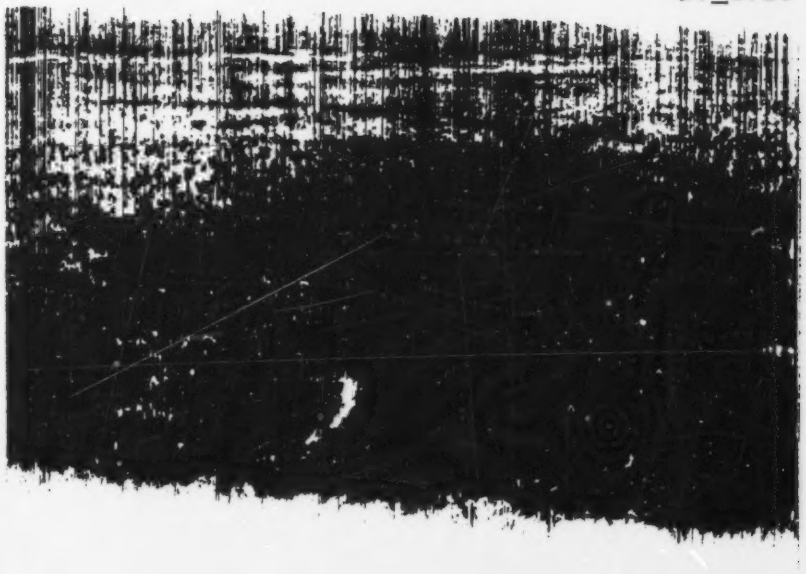

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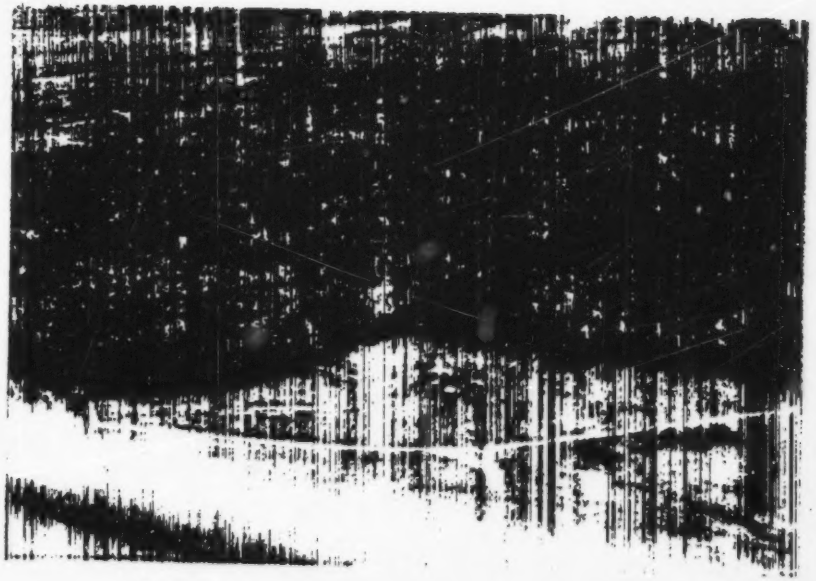

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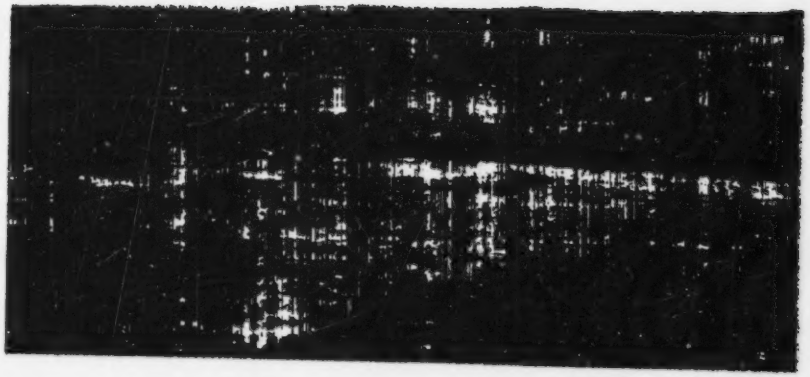

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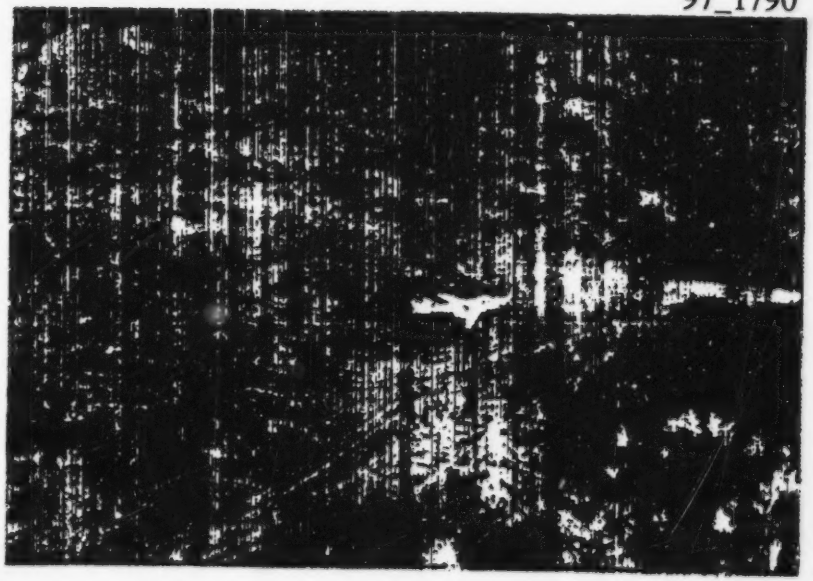

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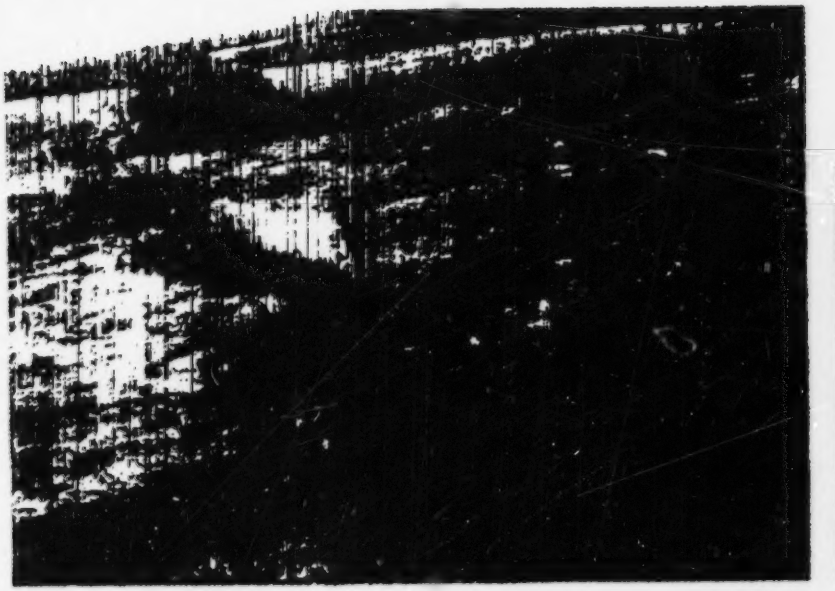

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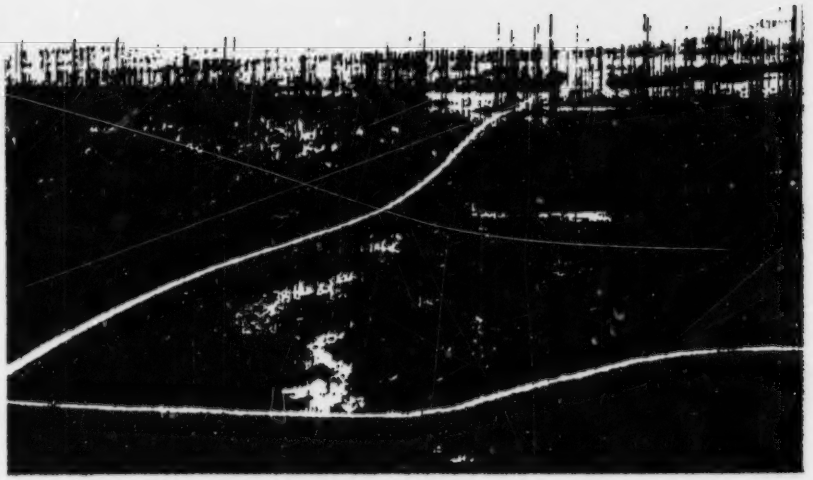

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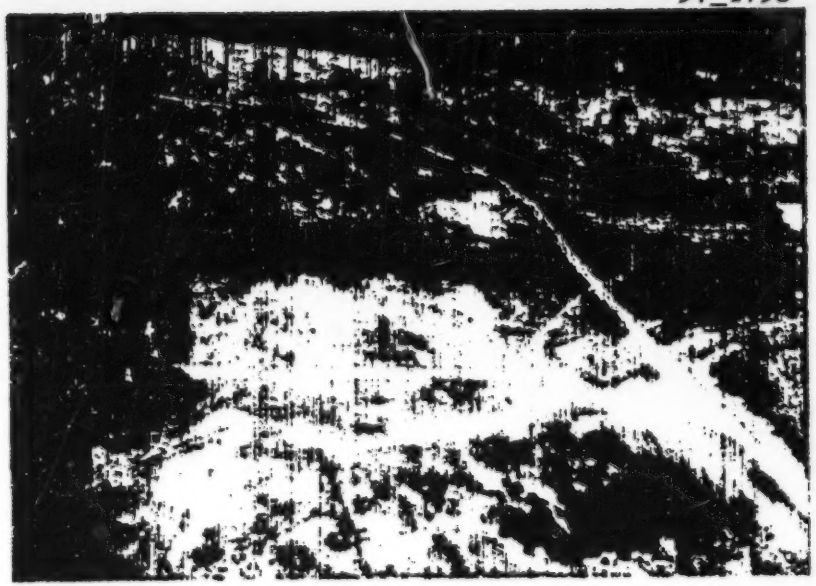

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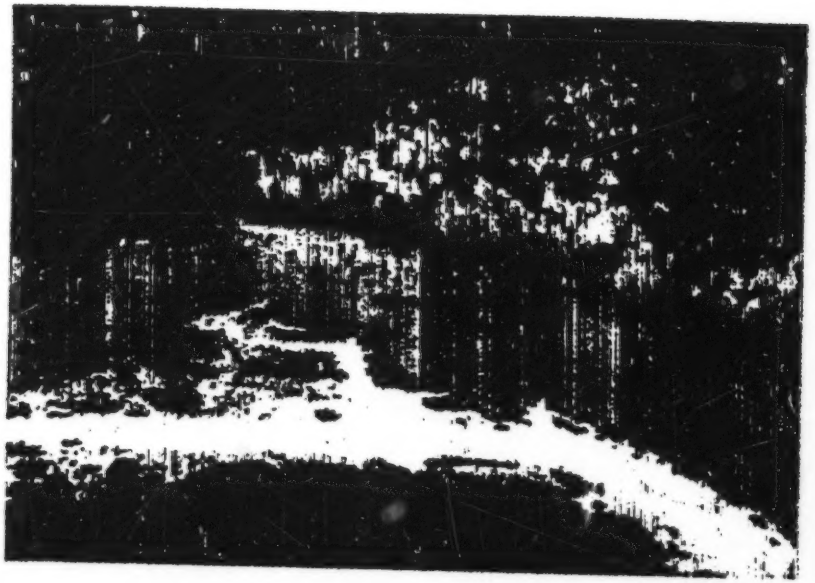

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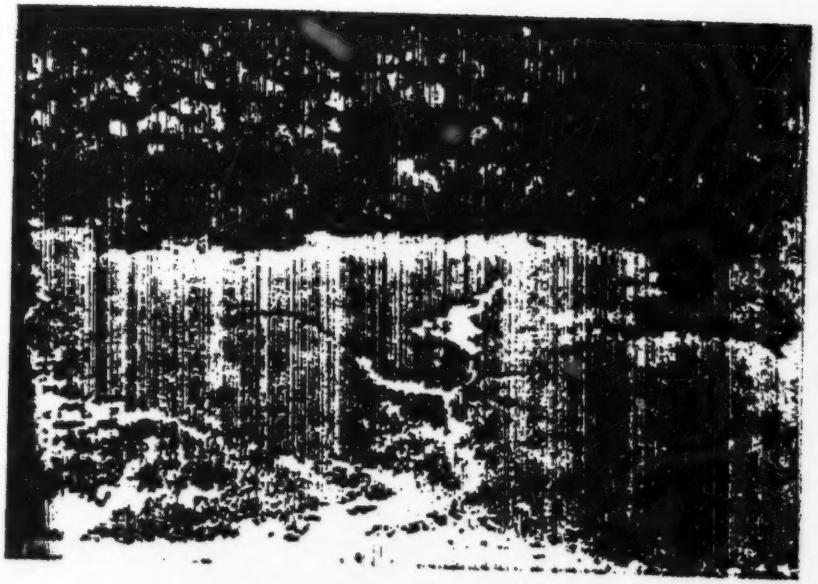

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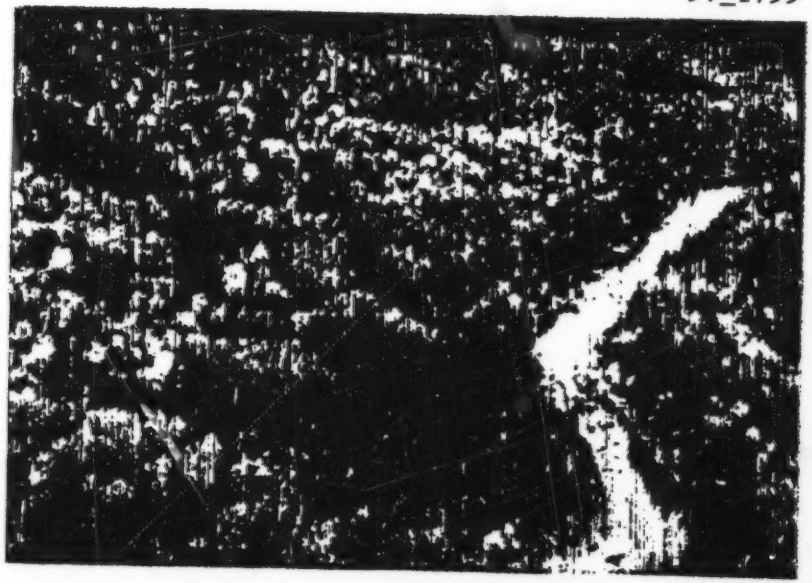

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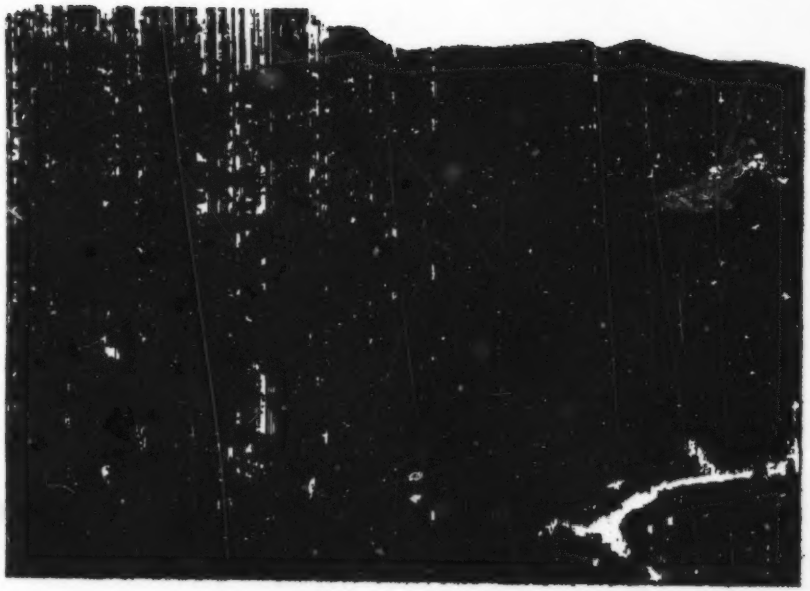

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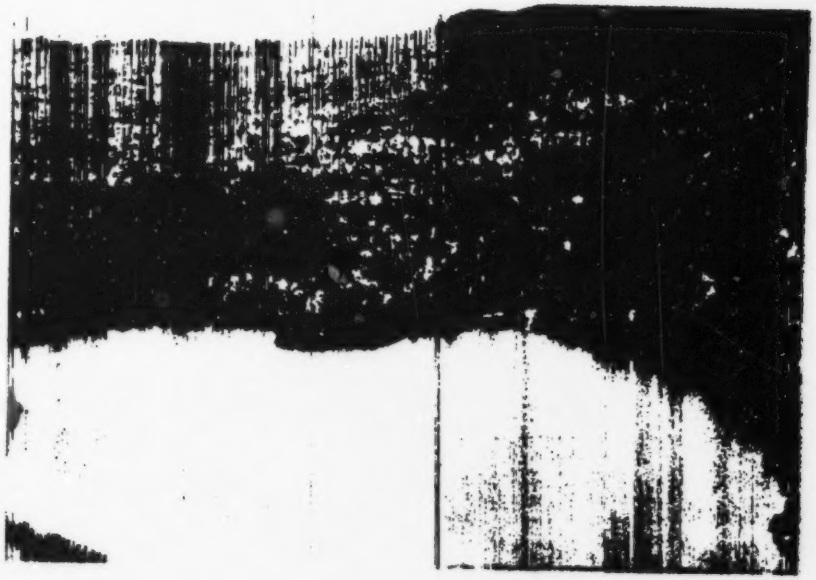

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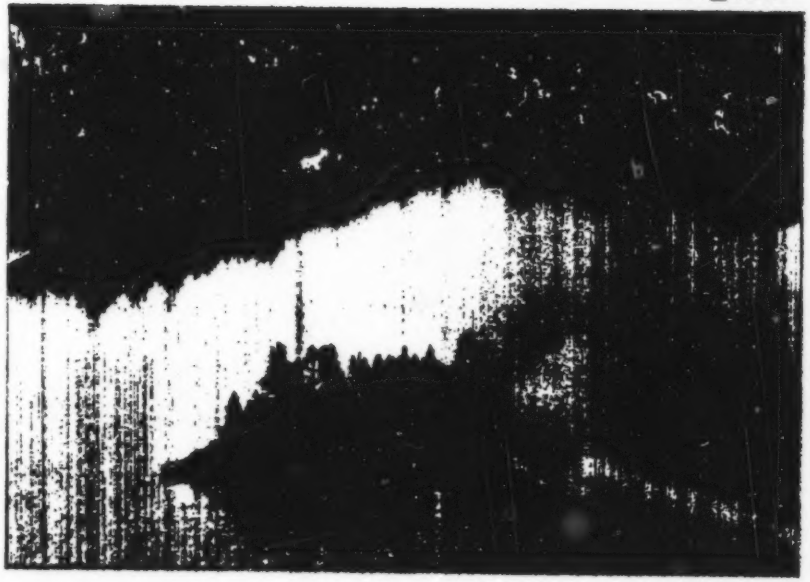

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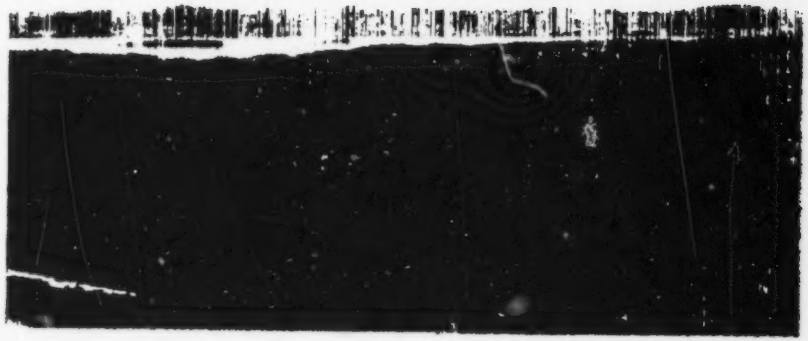

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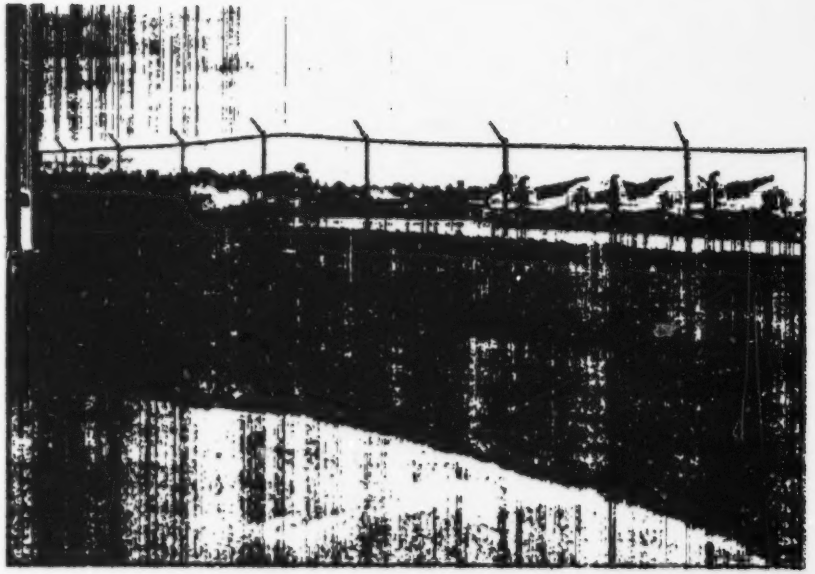

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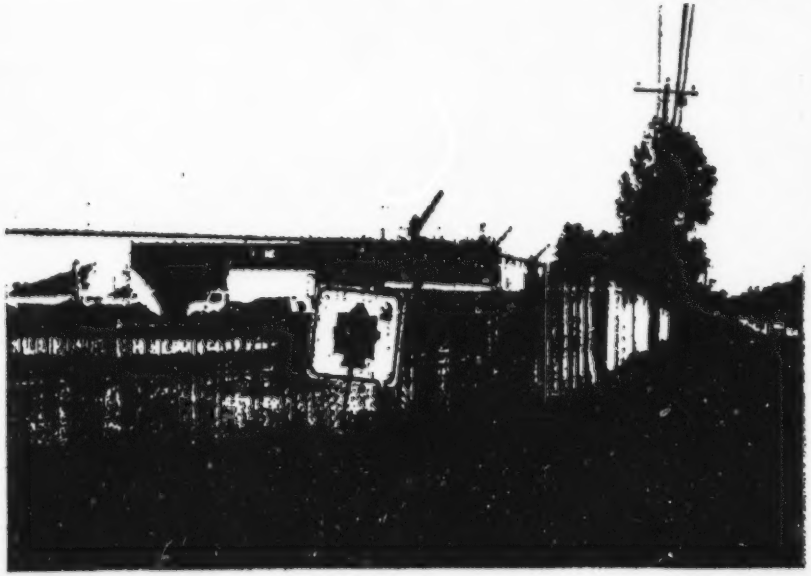

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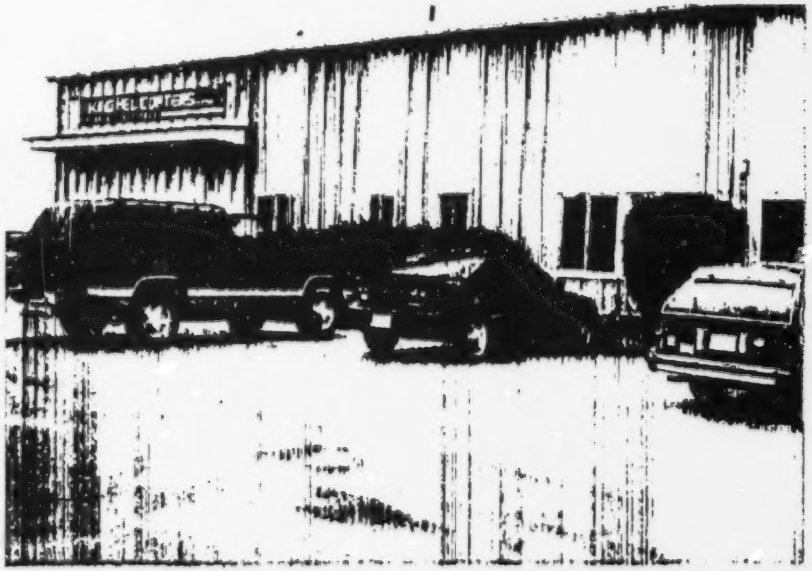

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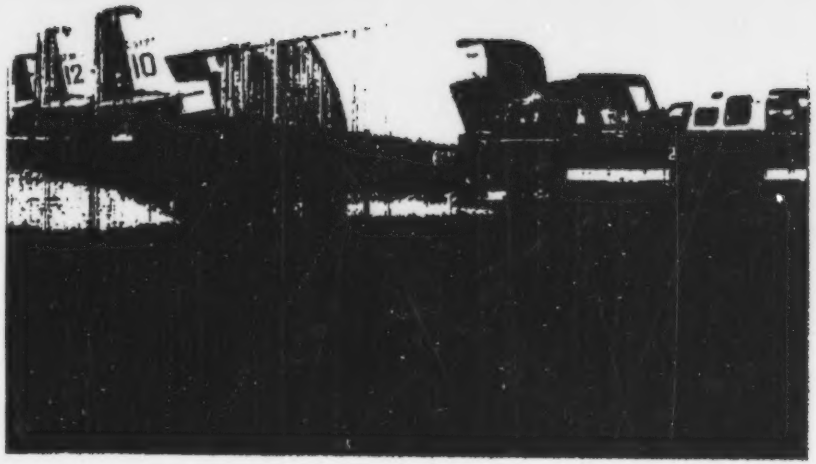

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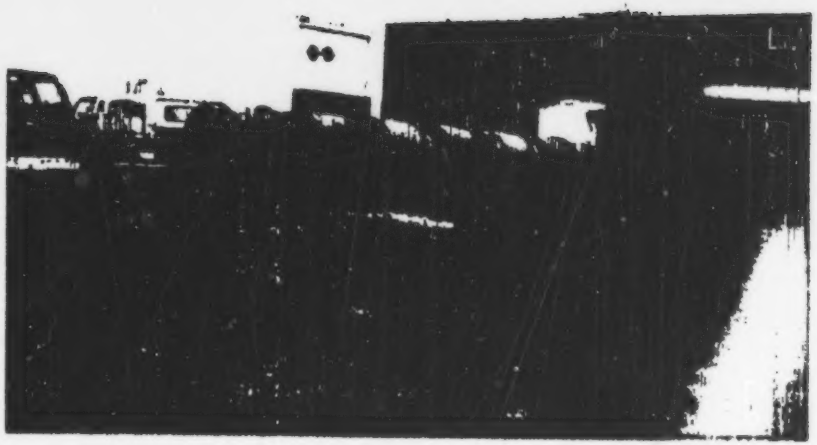

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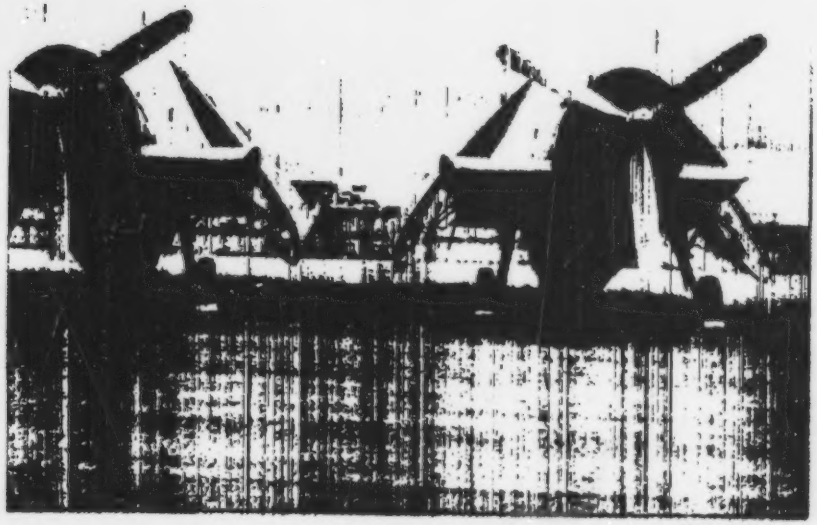

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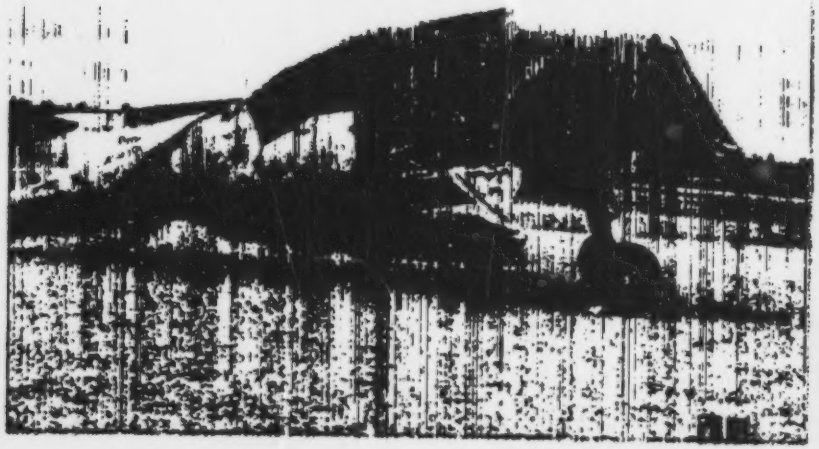

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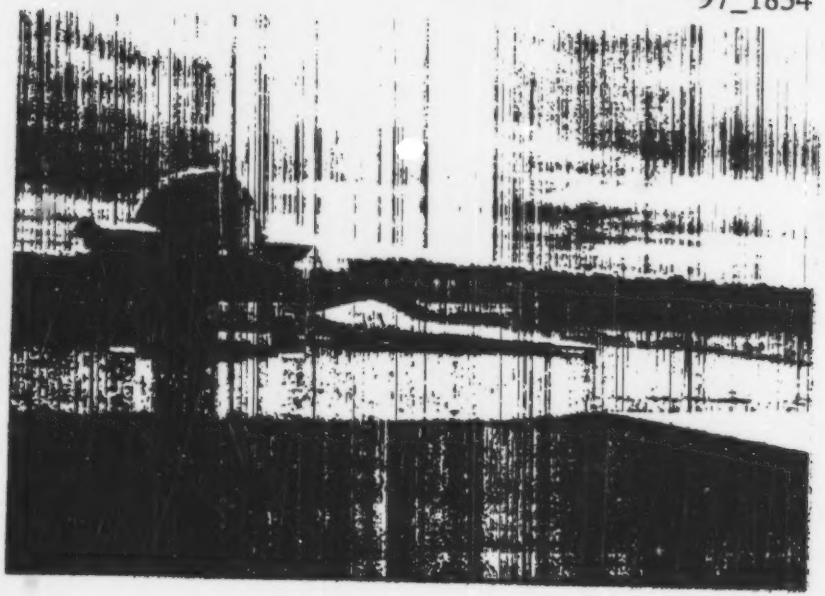

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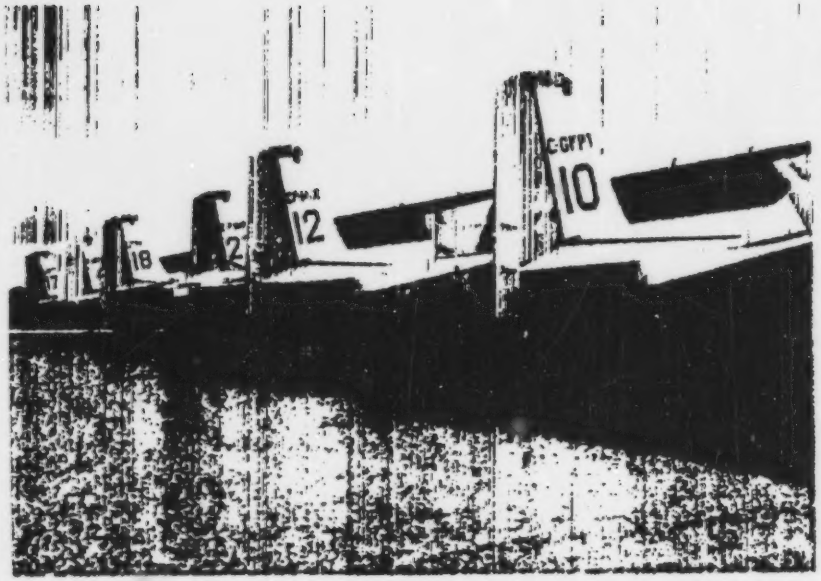

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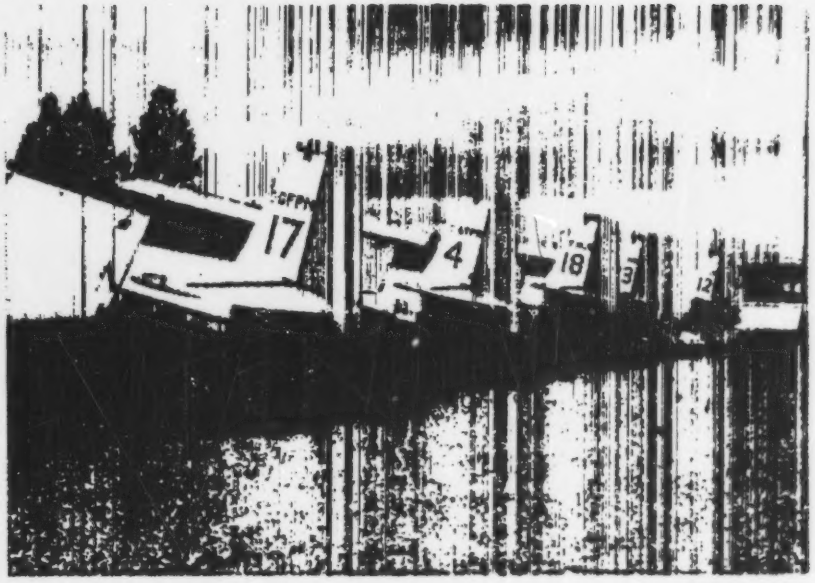

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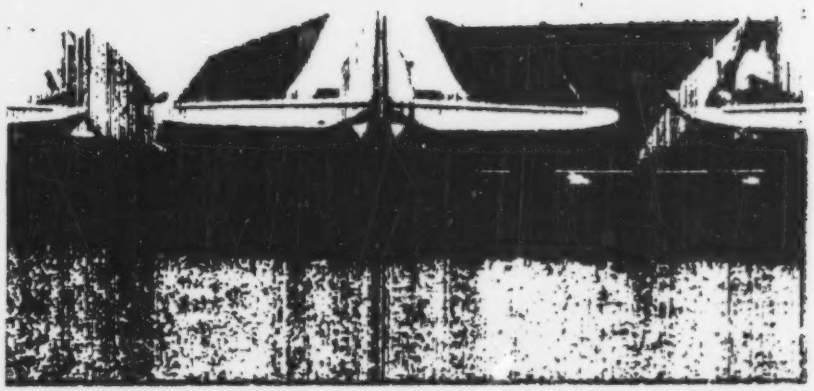

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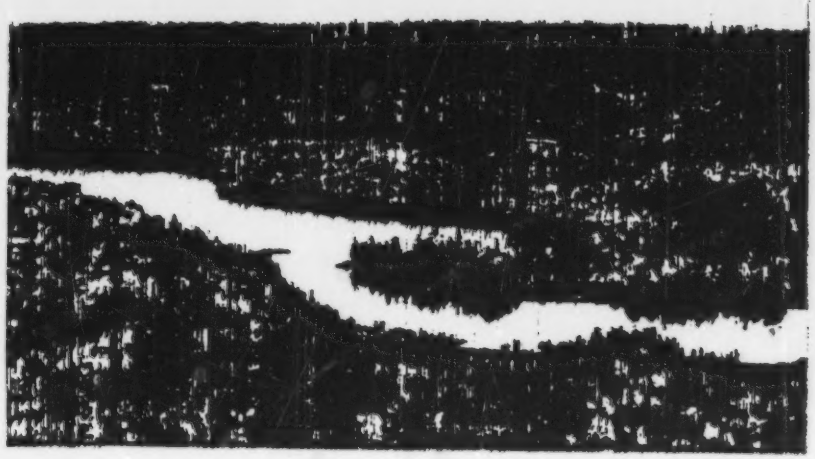

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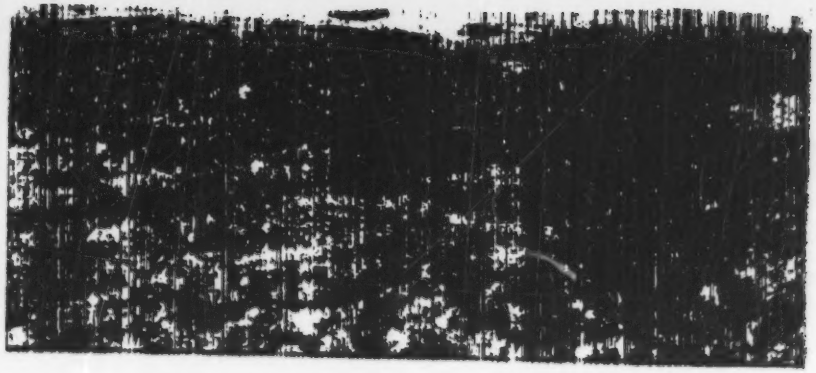

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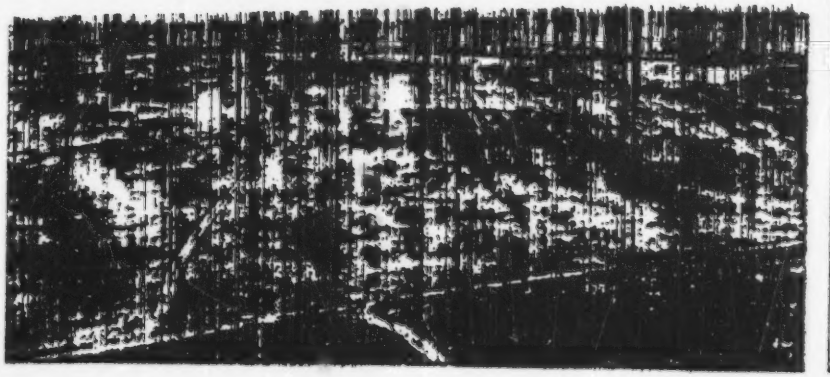

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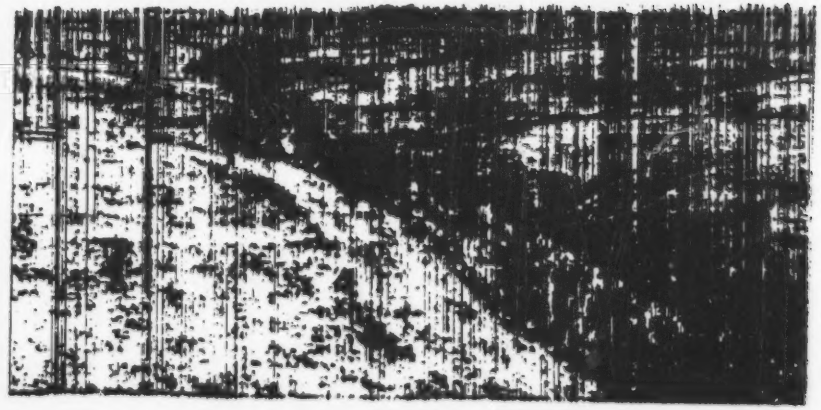

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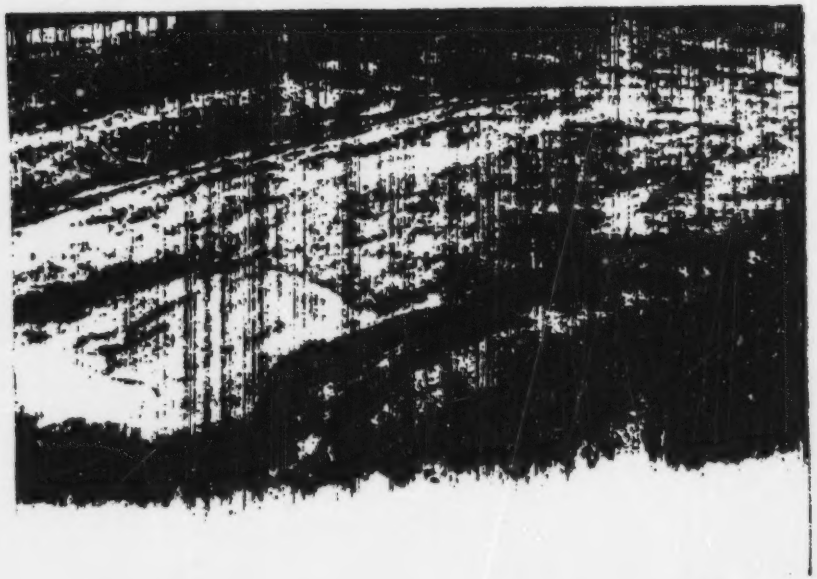

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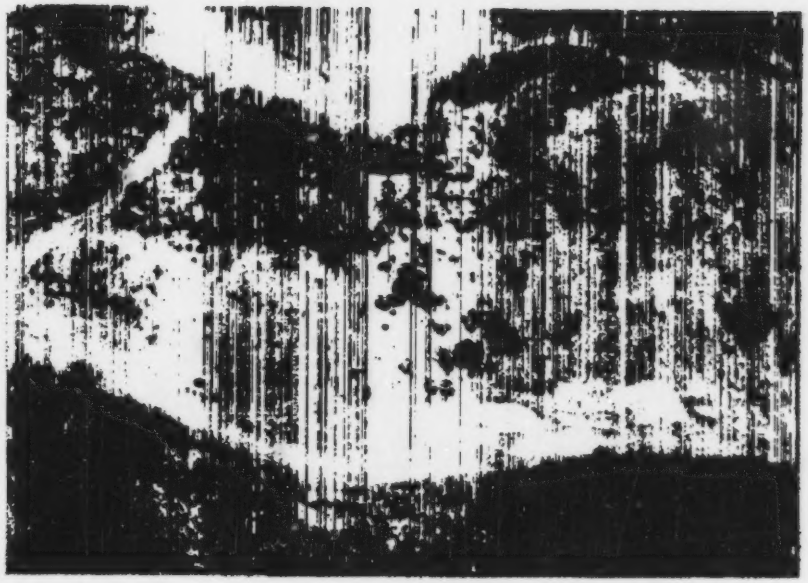

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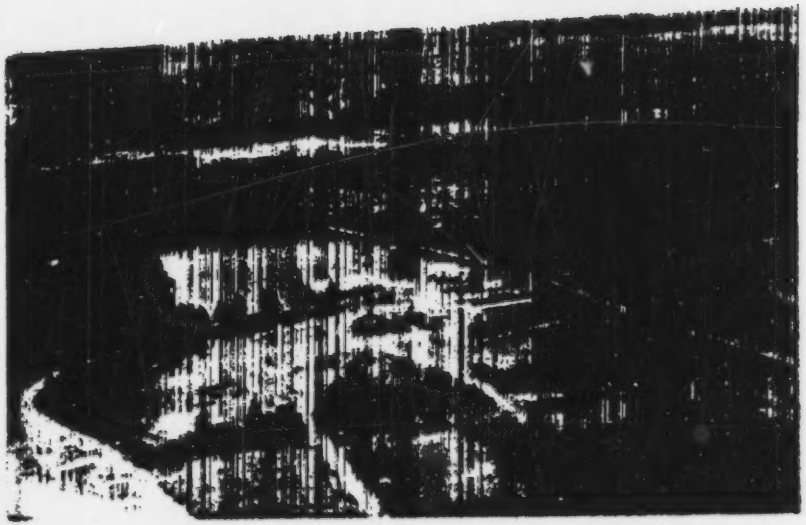

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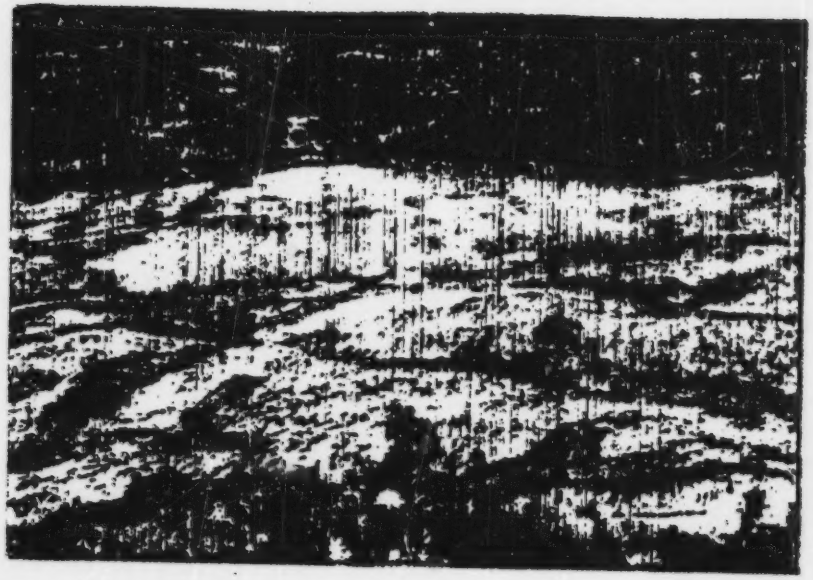

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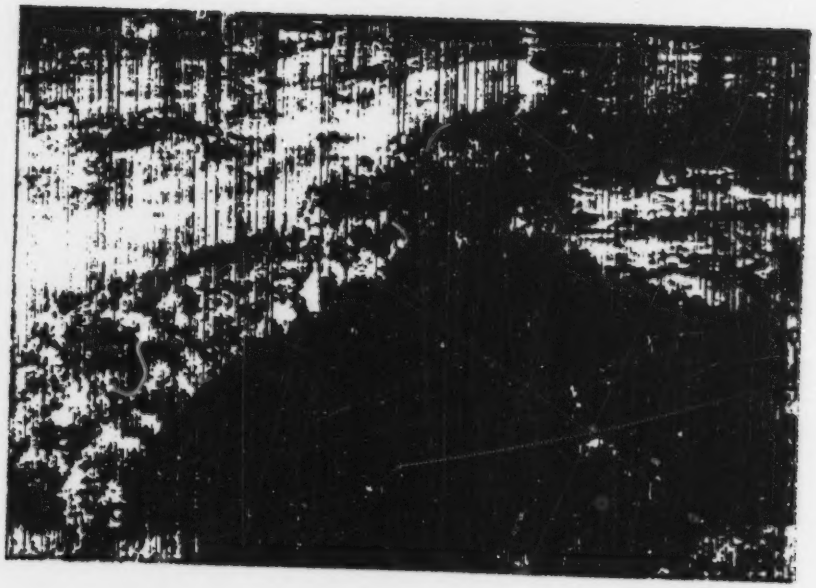

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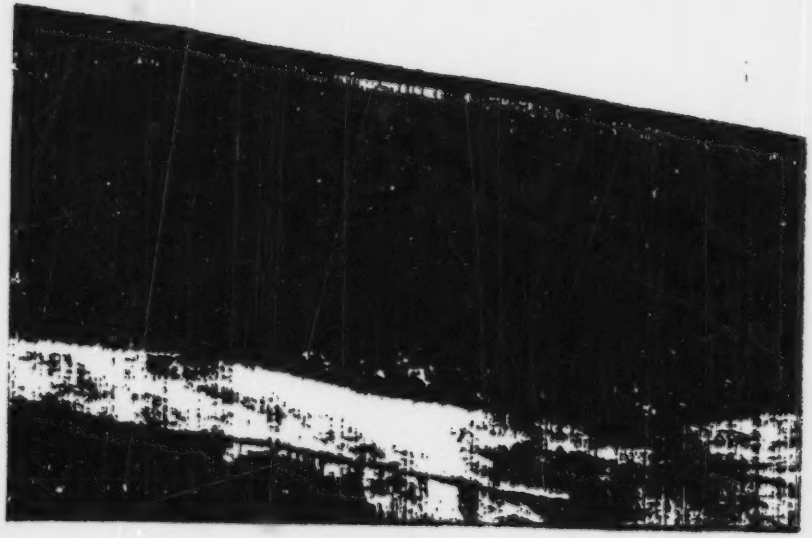

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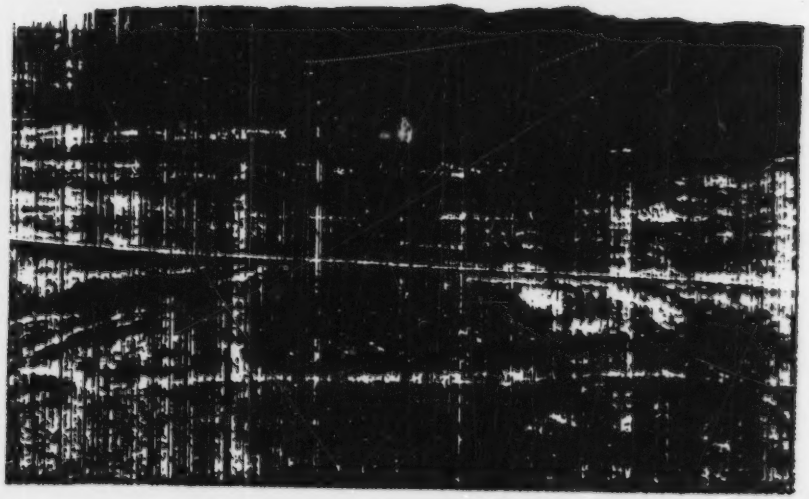

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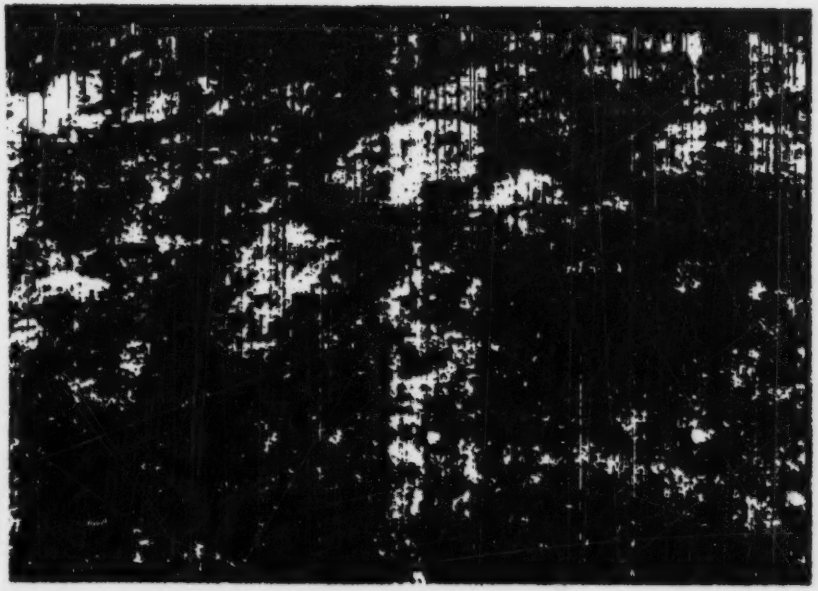

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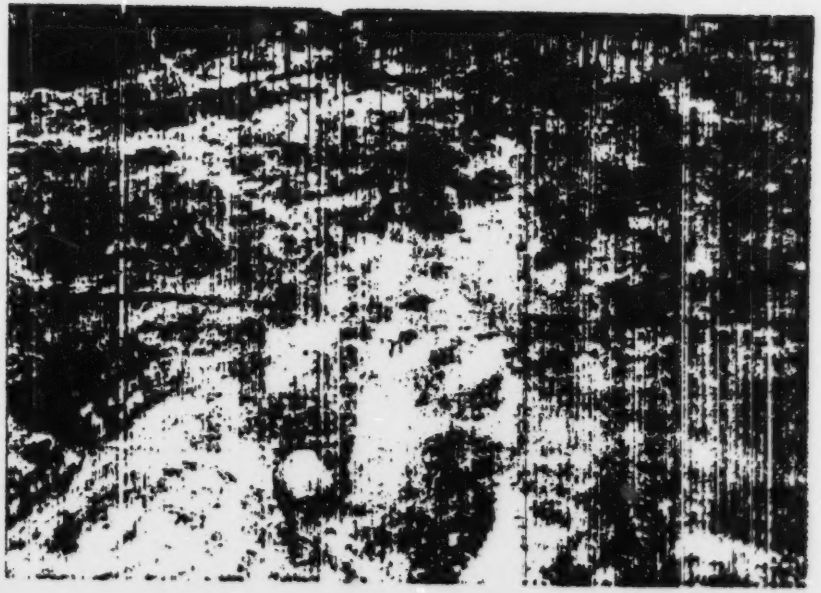

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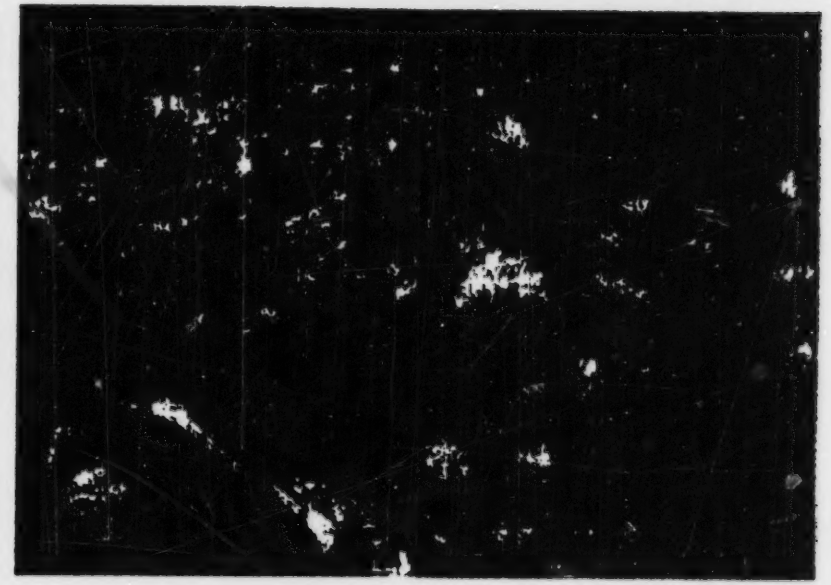

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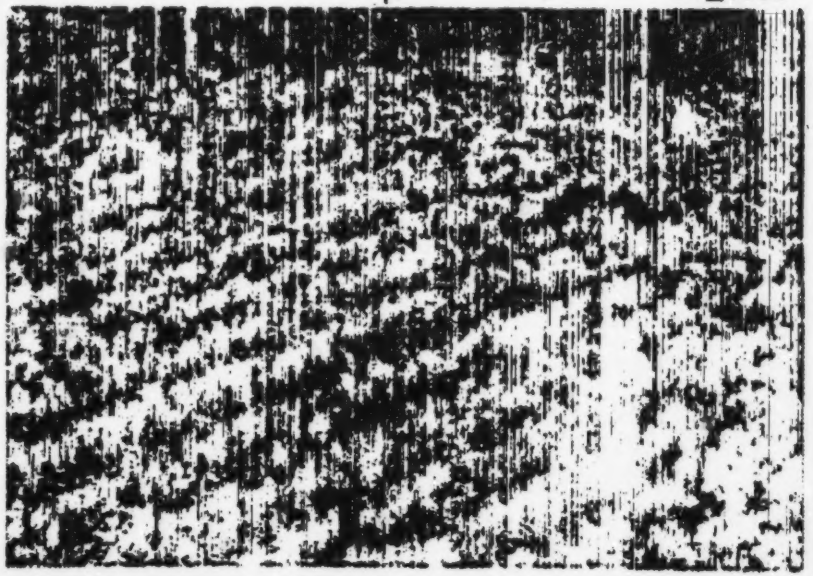

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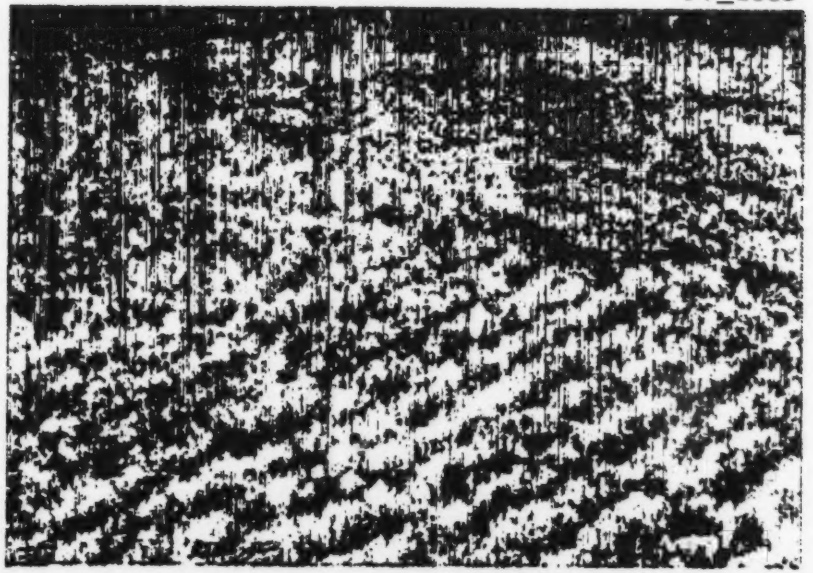

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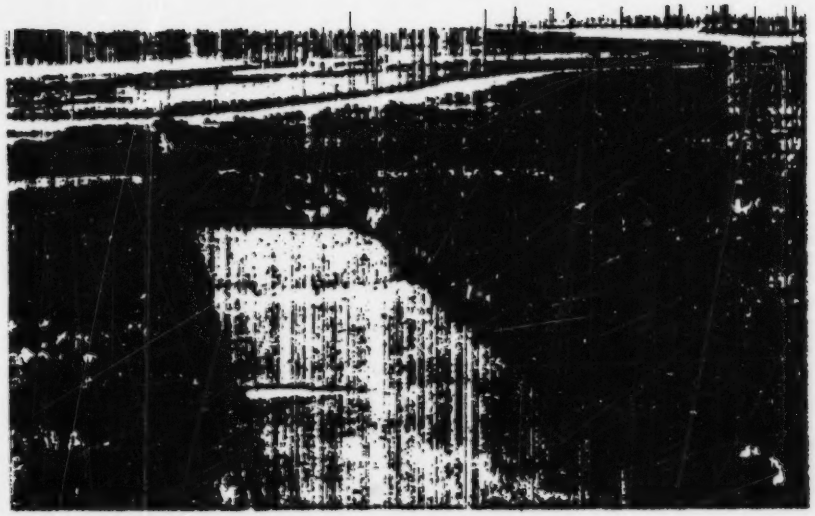

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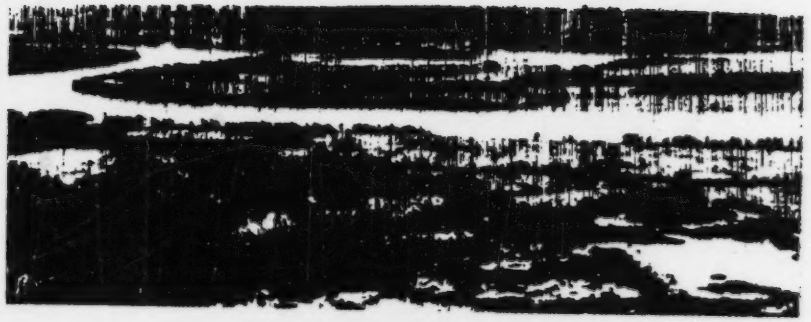

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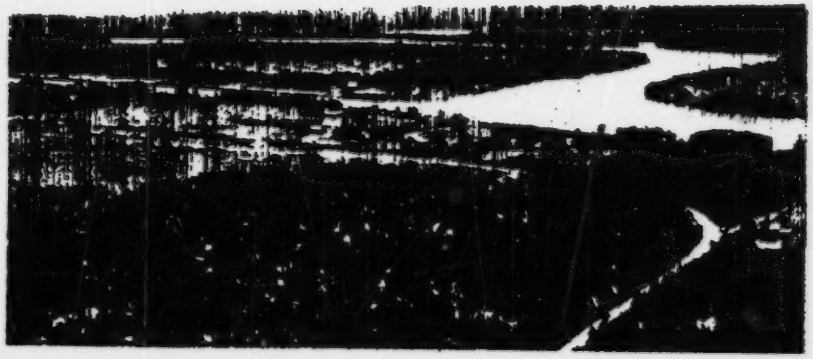

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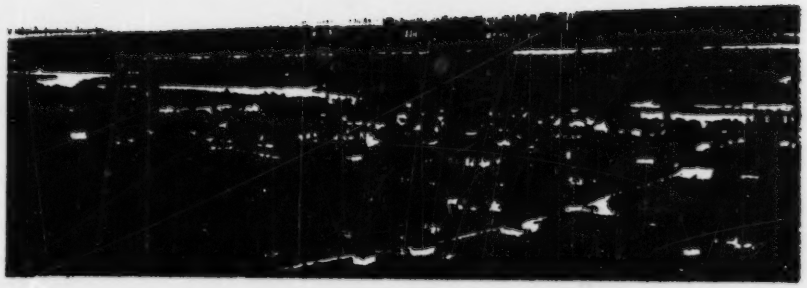

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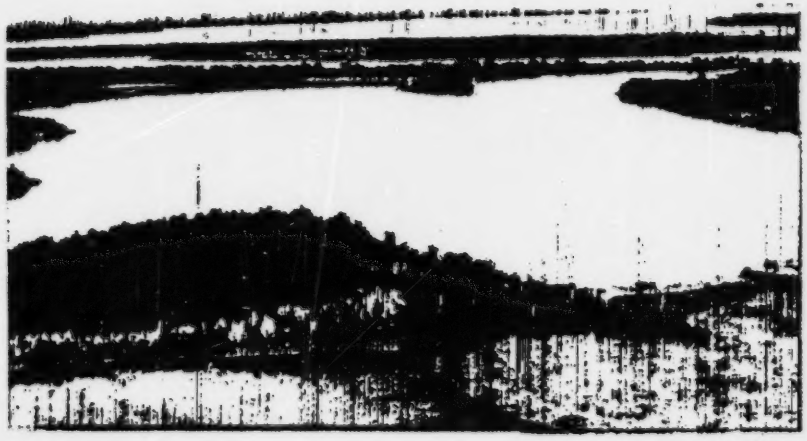

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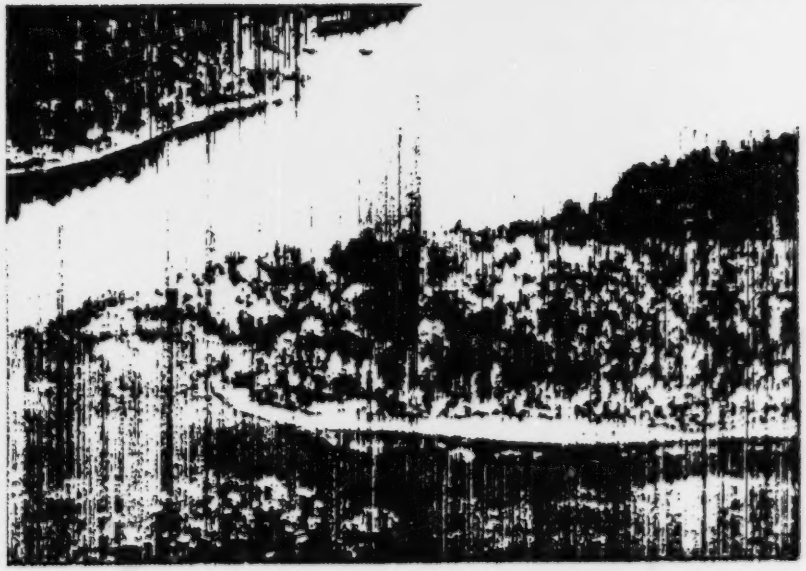

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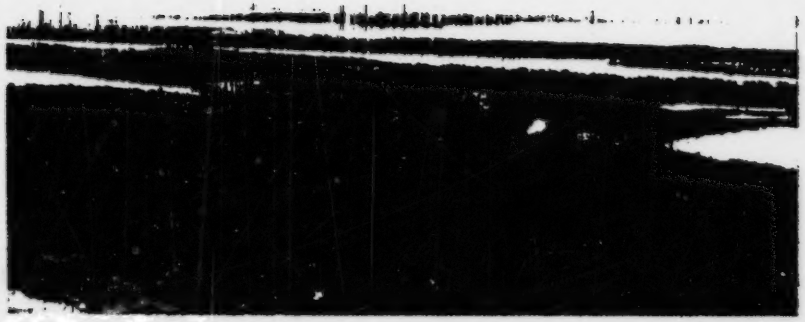

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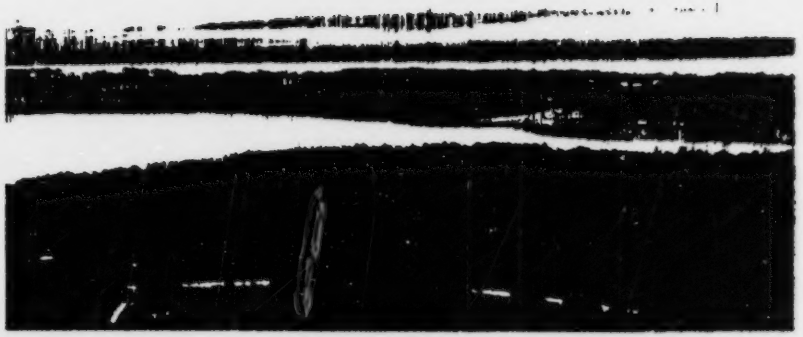

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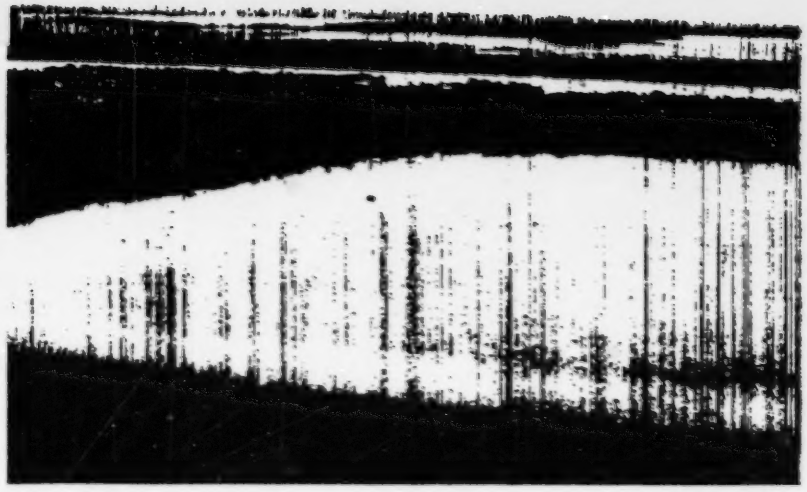

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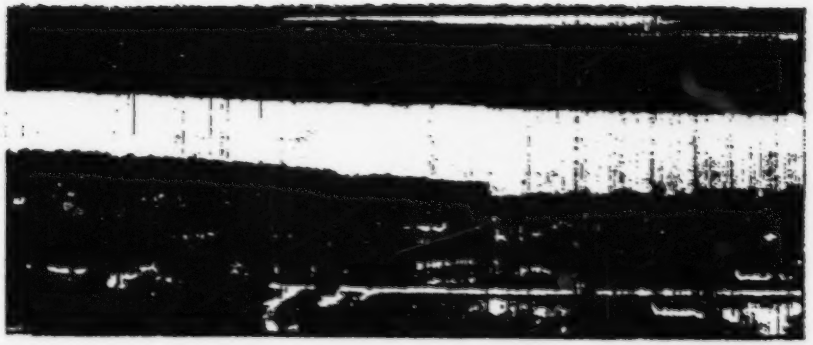

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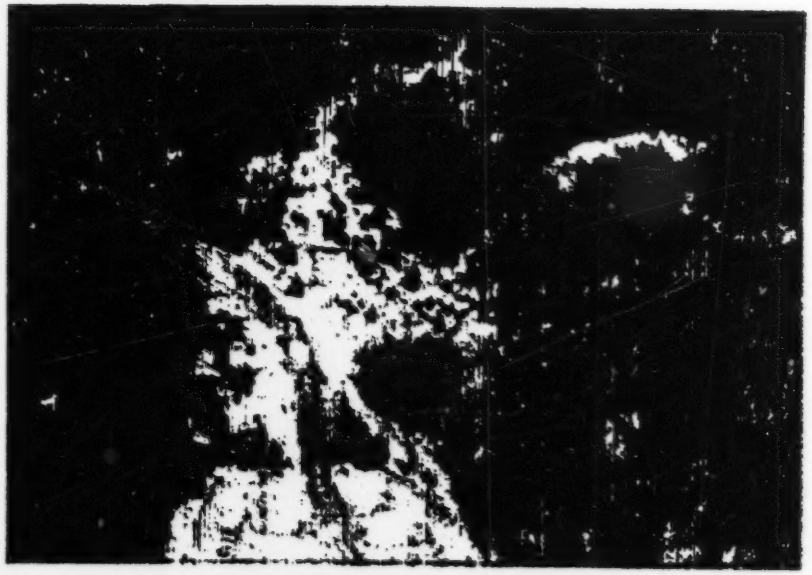

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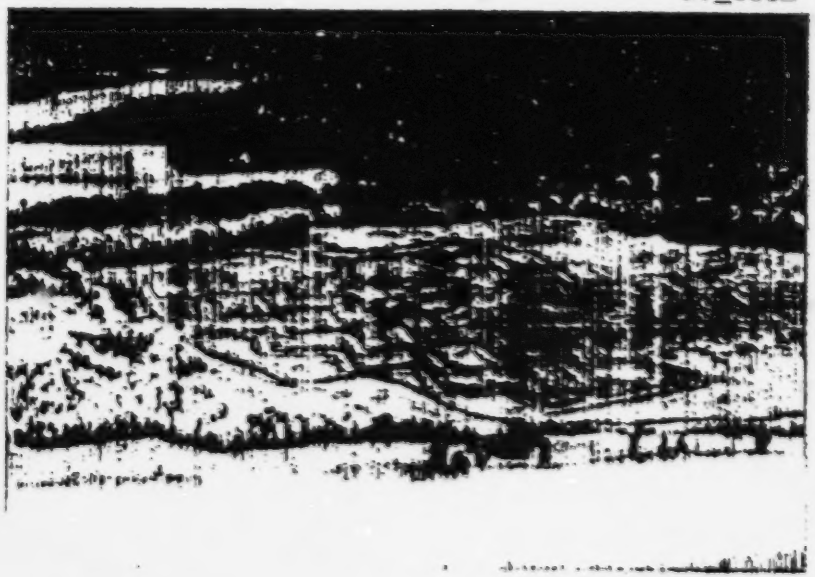

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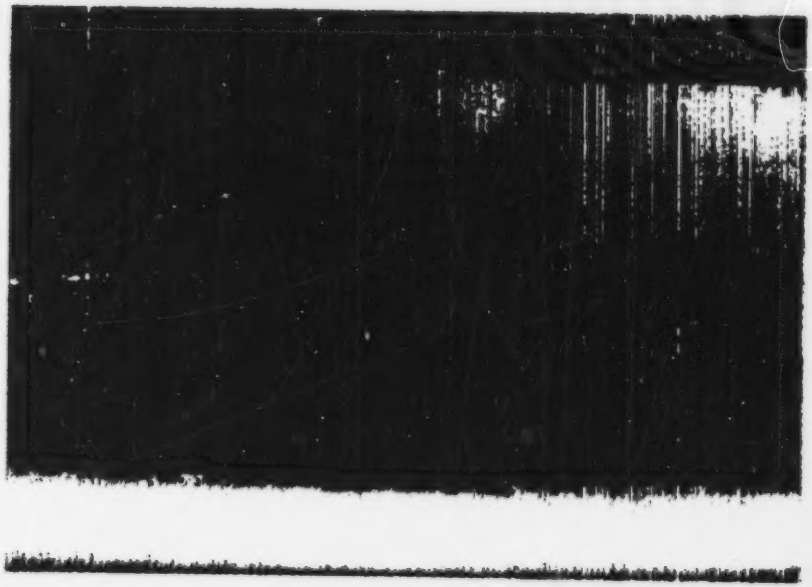

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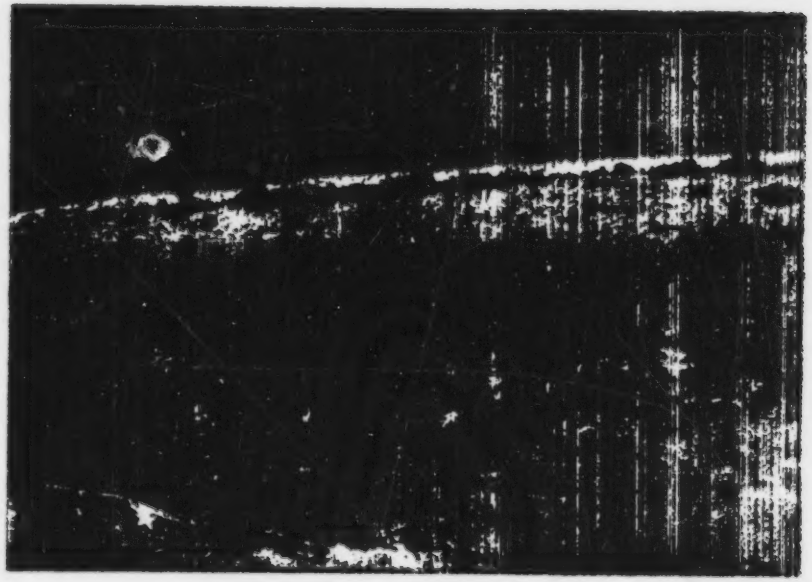

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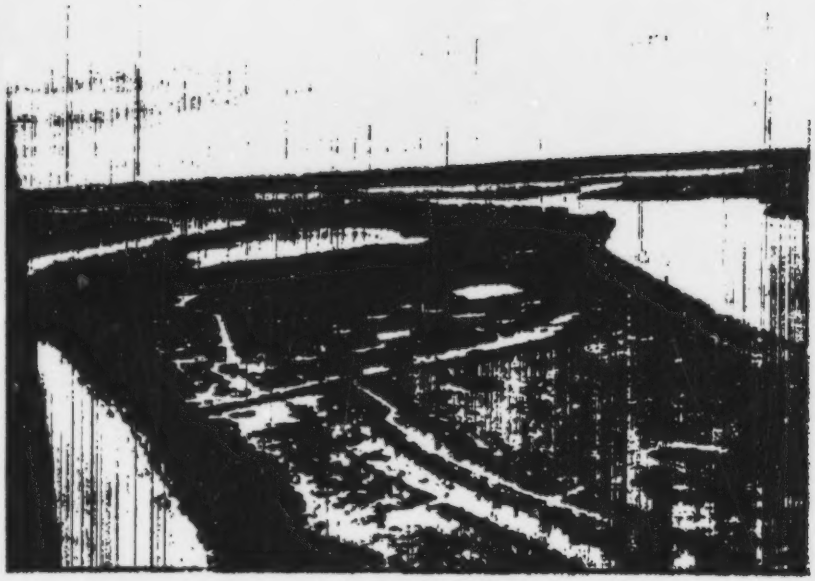

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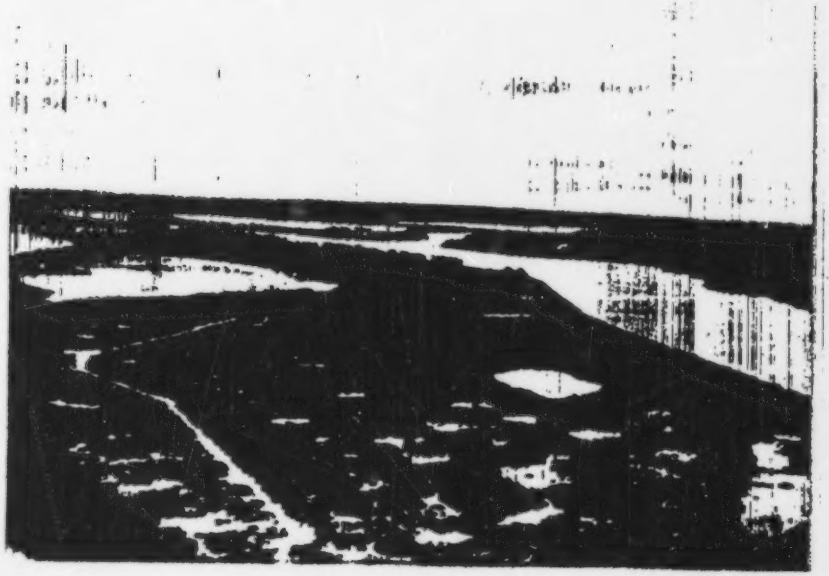

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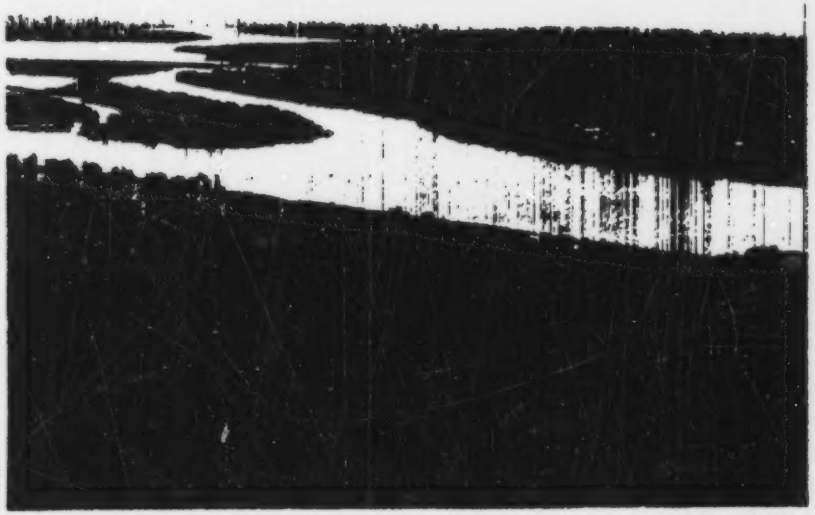

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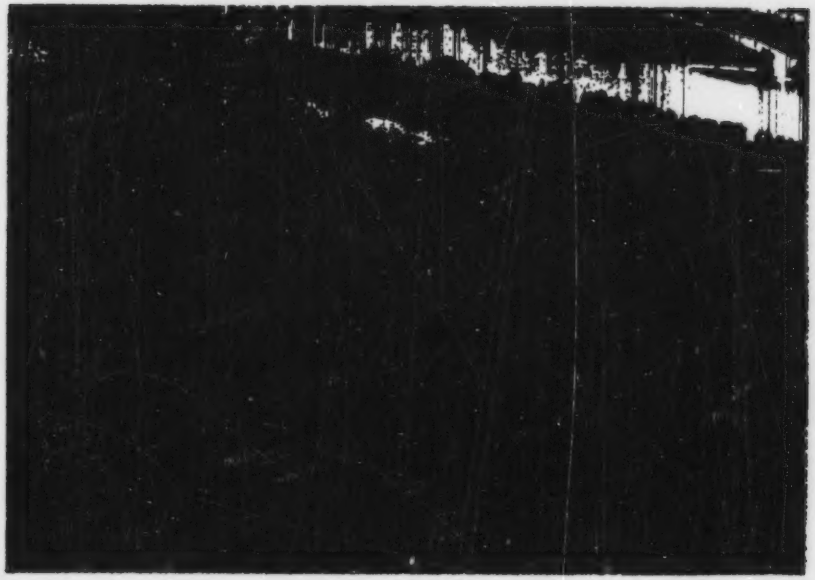

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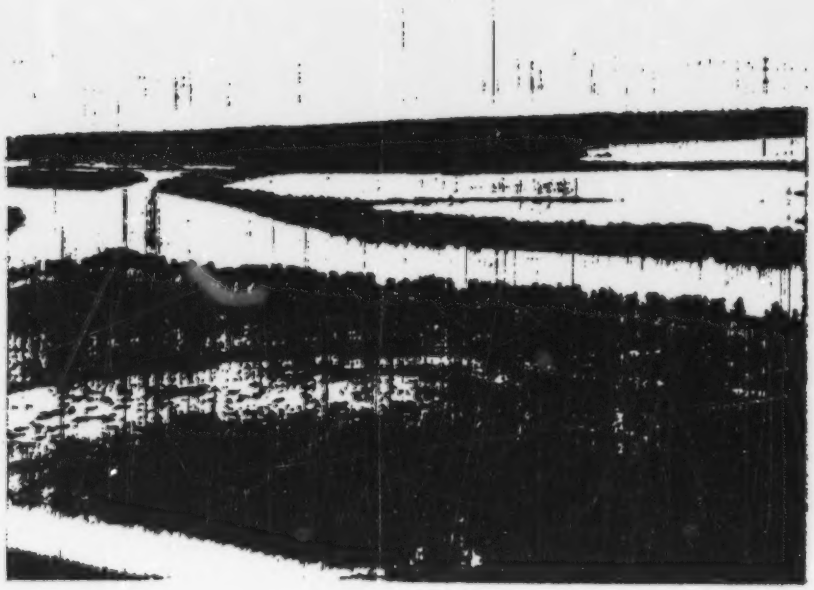

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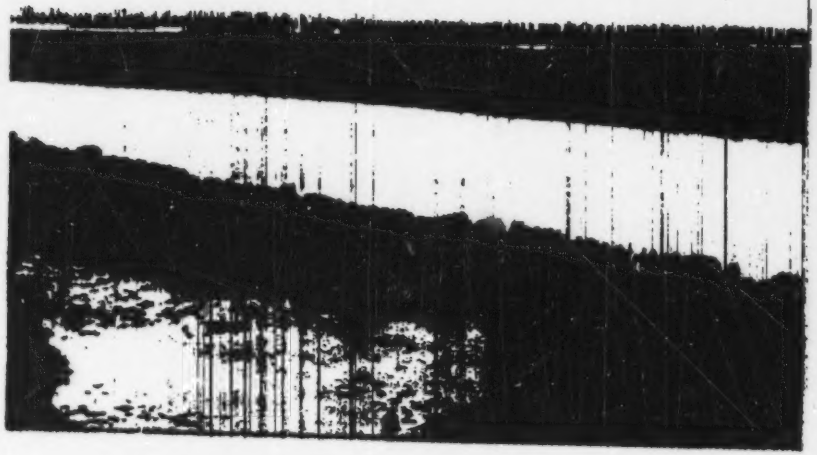

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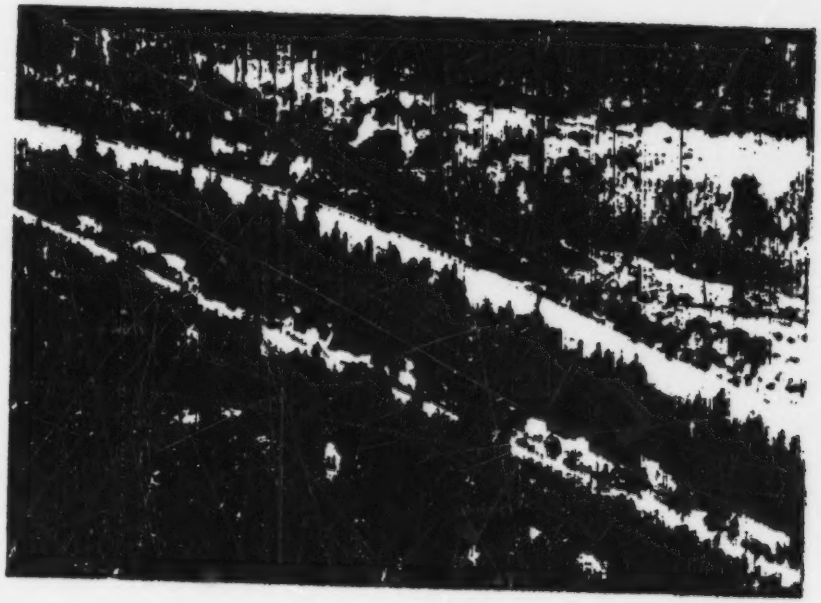

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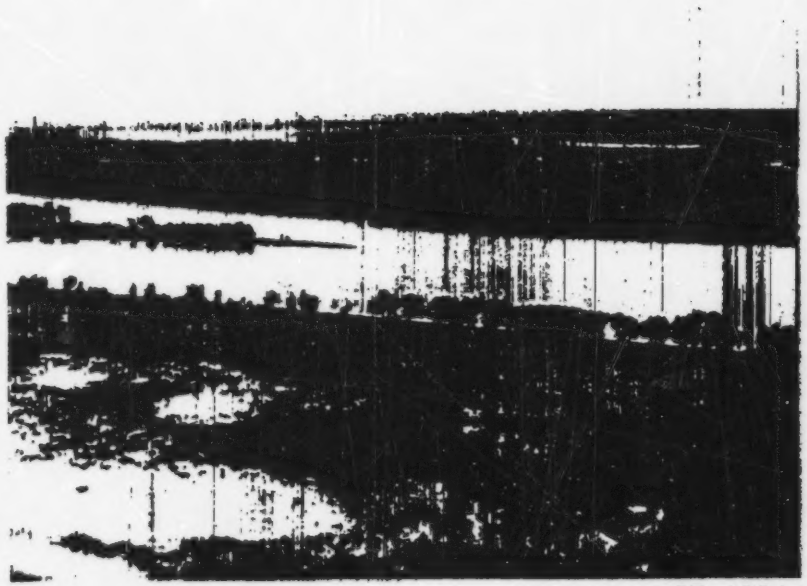

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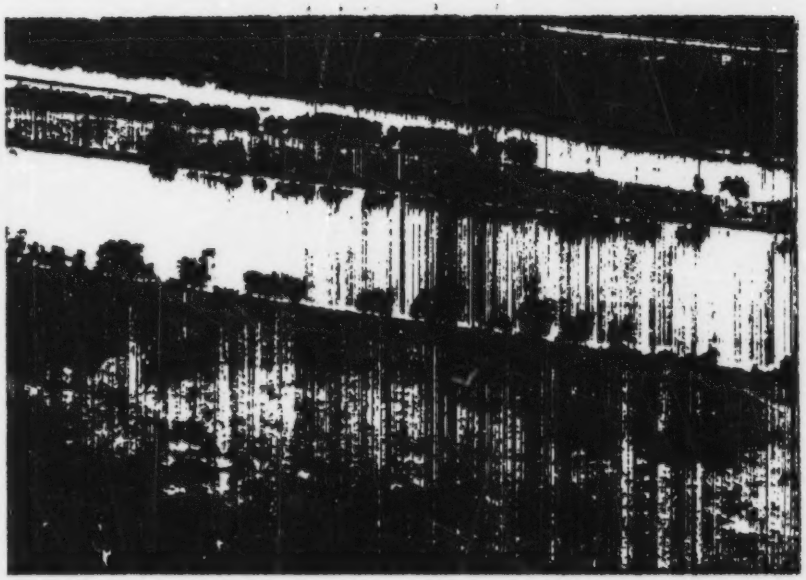

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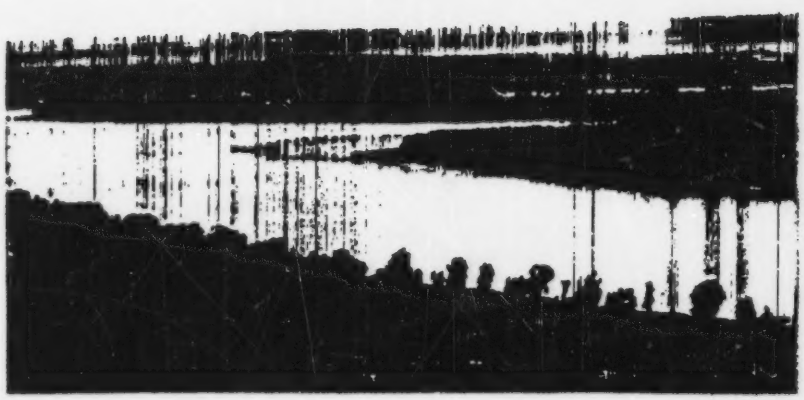

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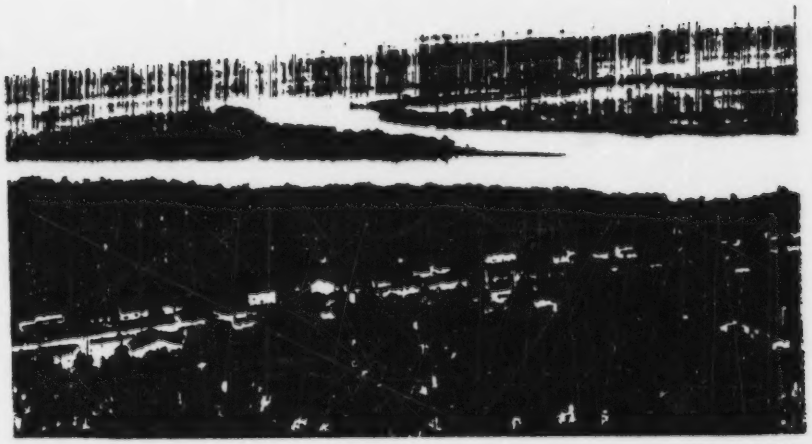

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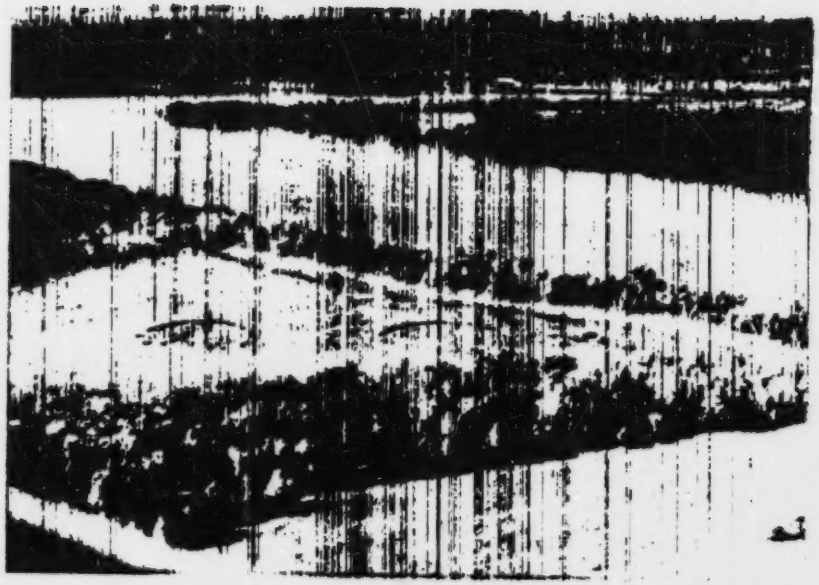

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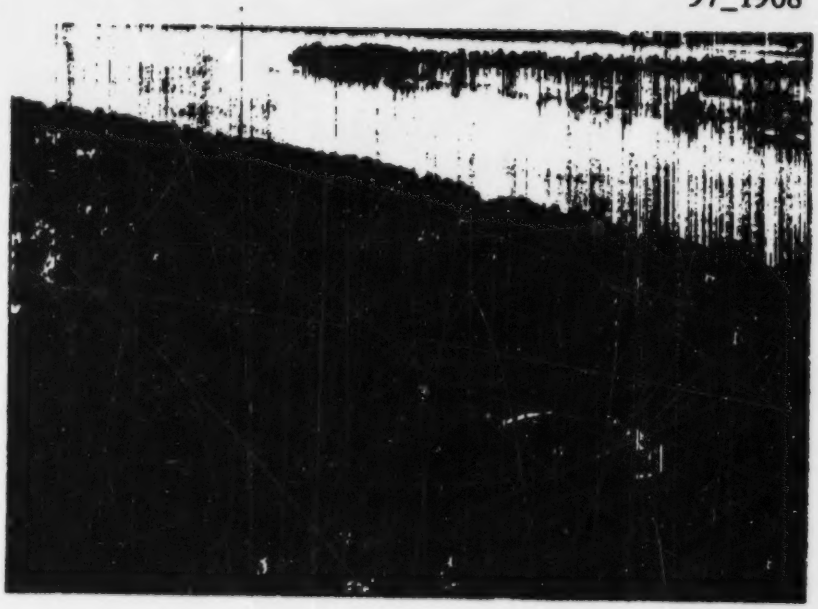

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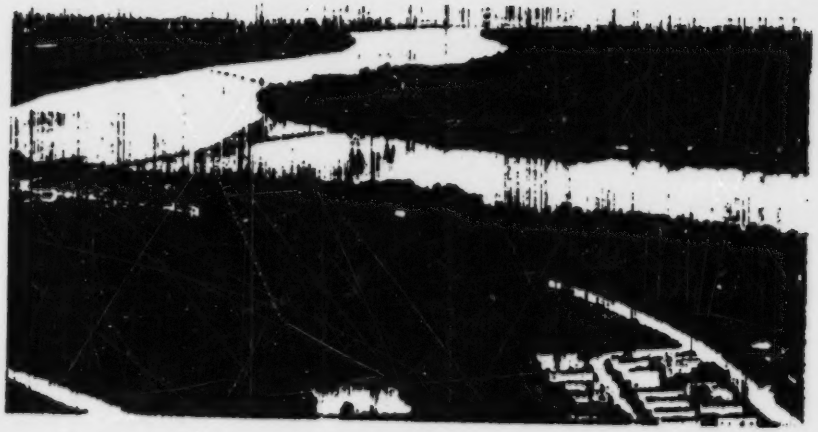

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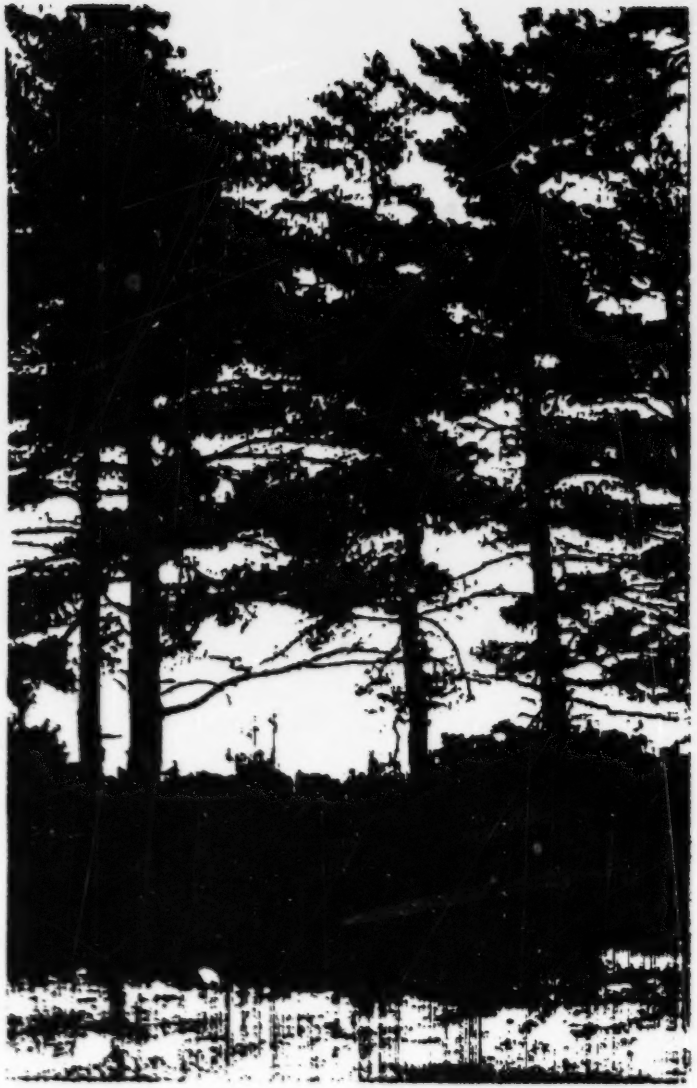

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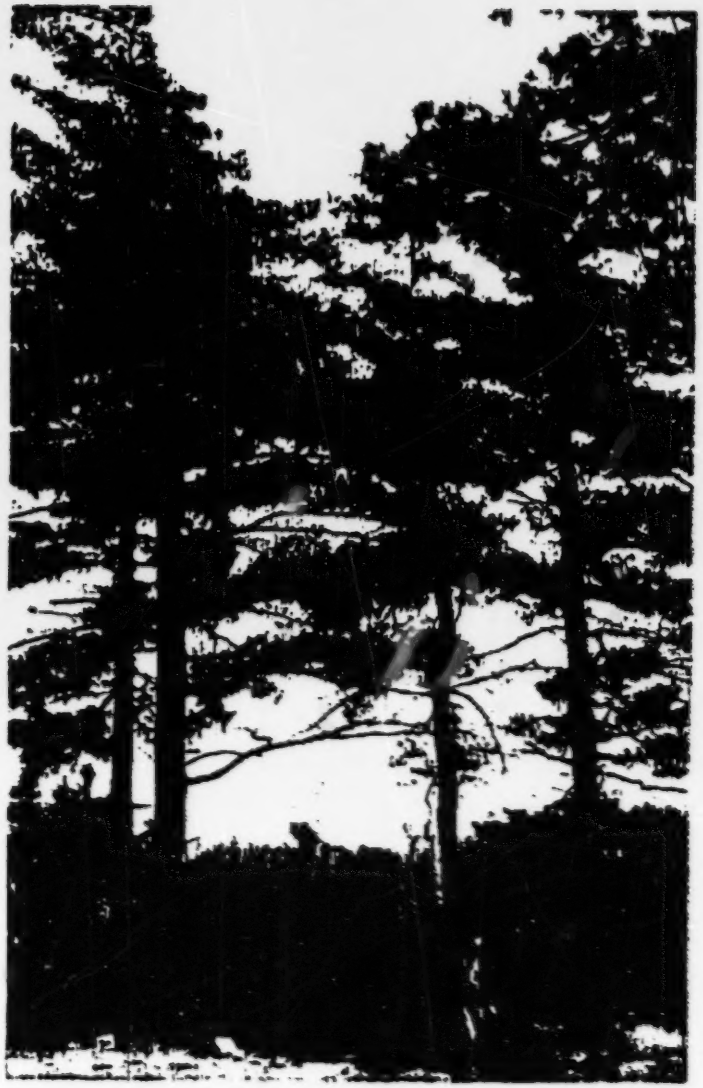

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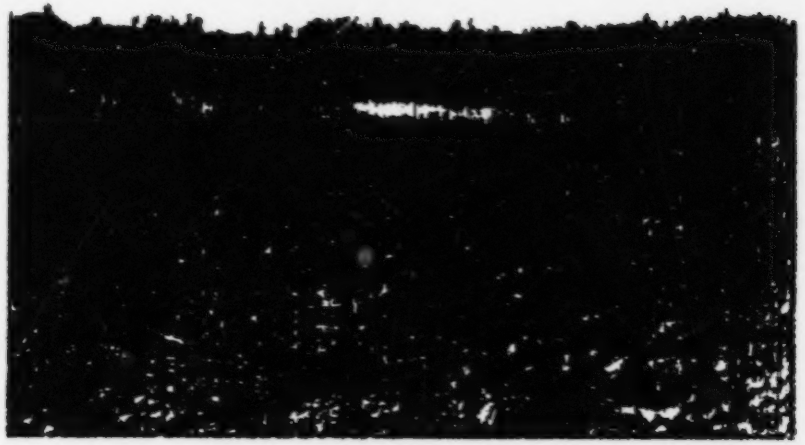

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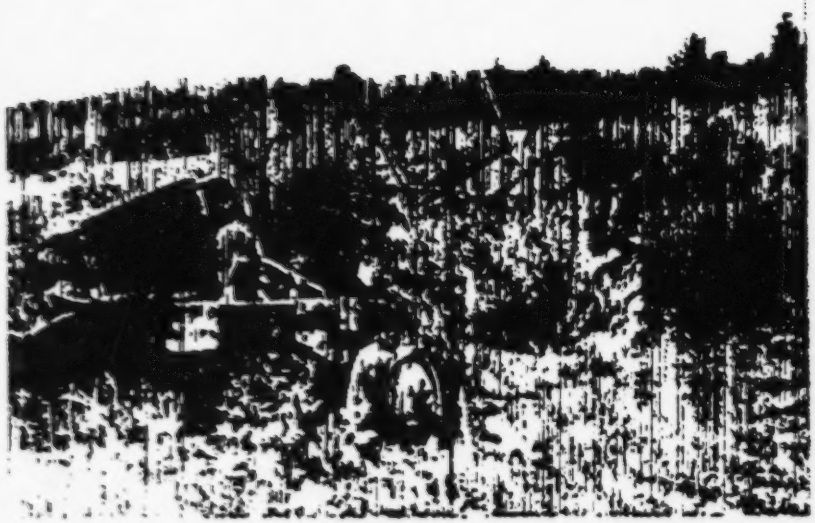

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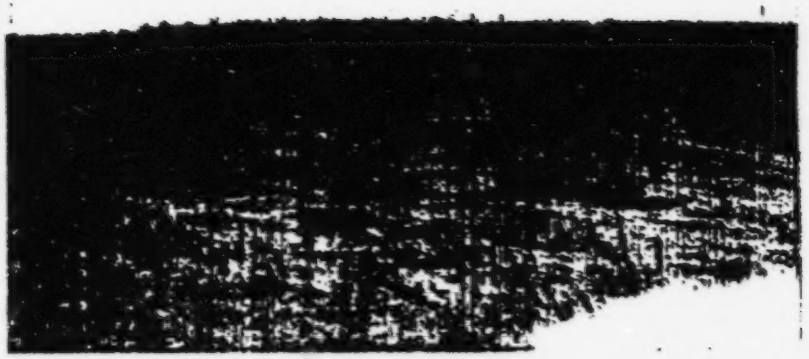

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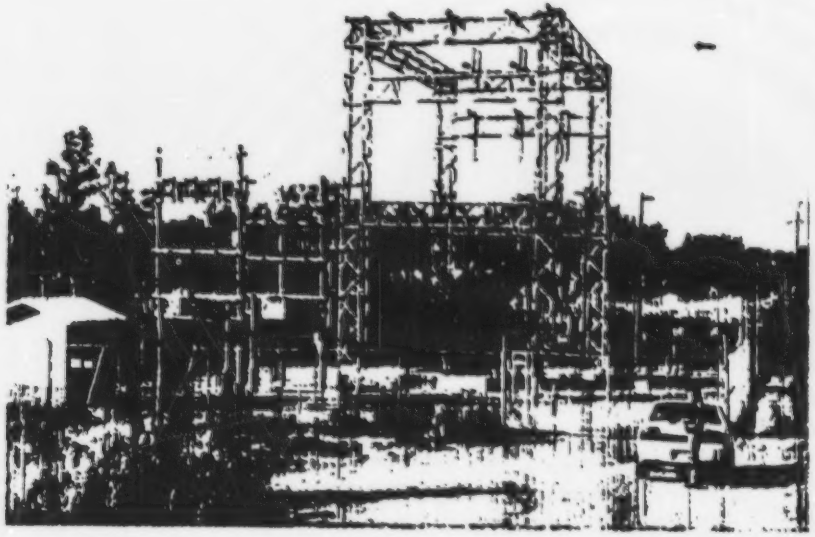

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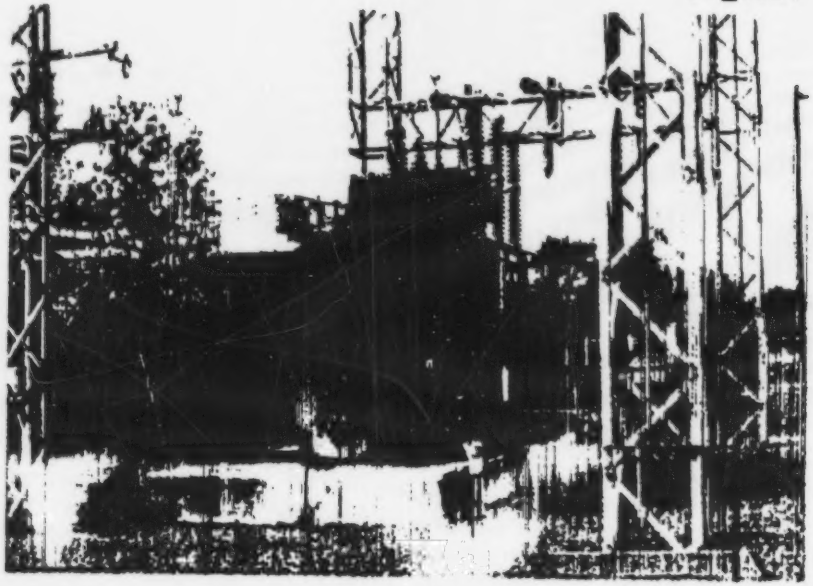

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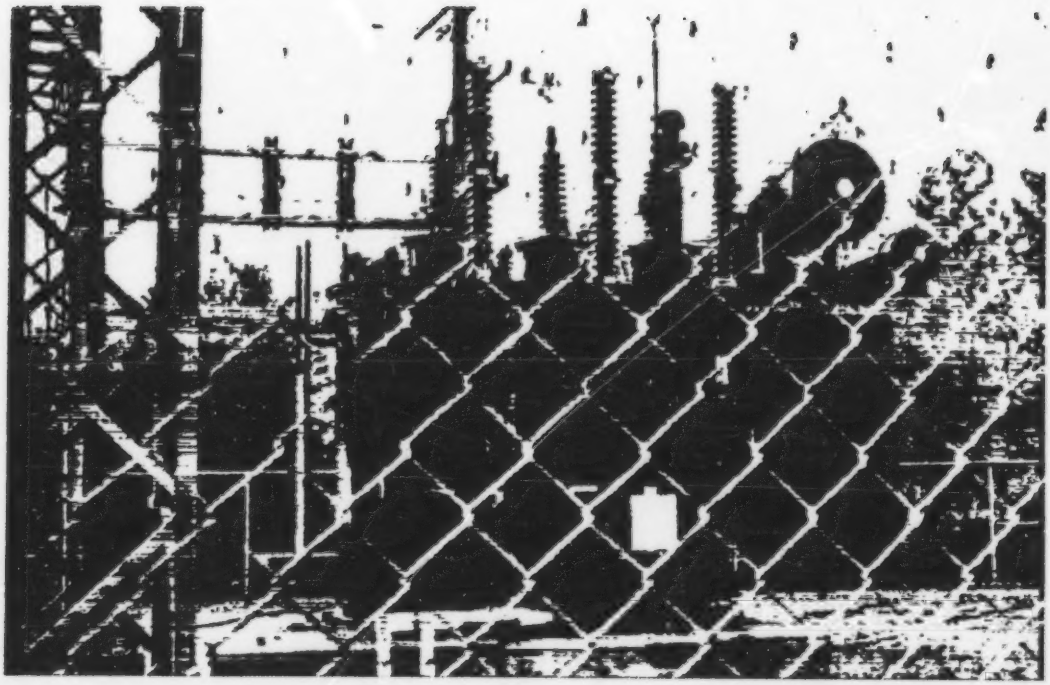


97_1938

CAGETOWN RANGE AND TRAINING AREA
Aerial Photos Nov 95 (Prepared by Halls Stubbs GS GIS)

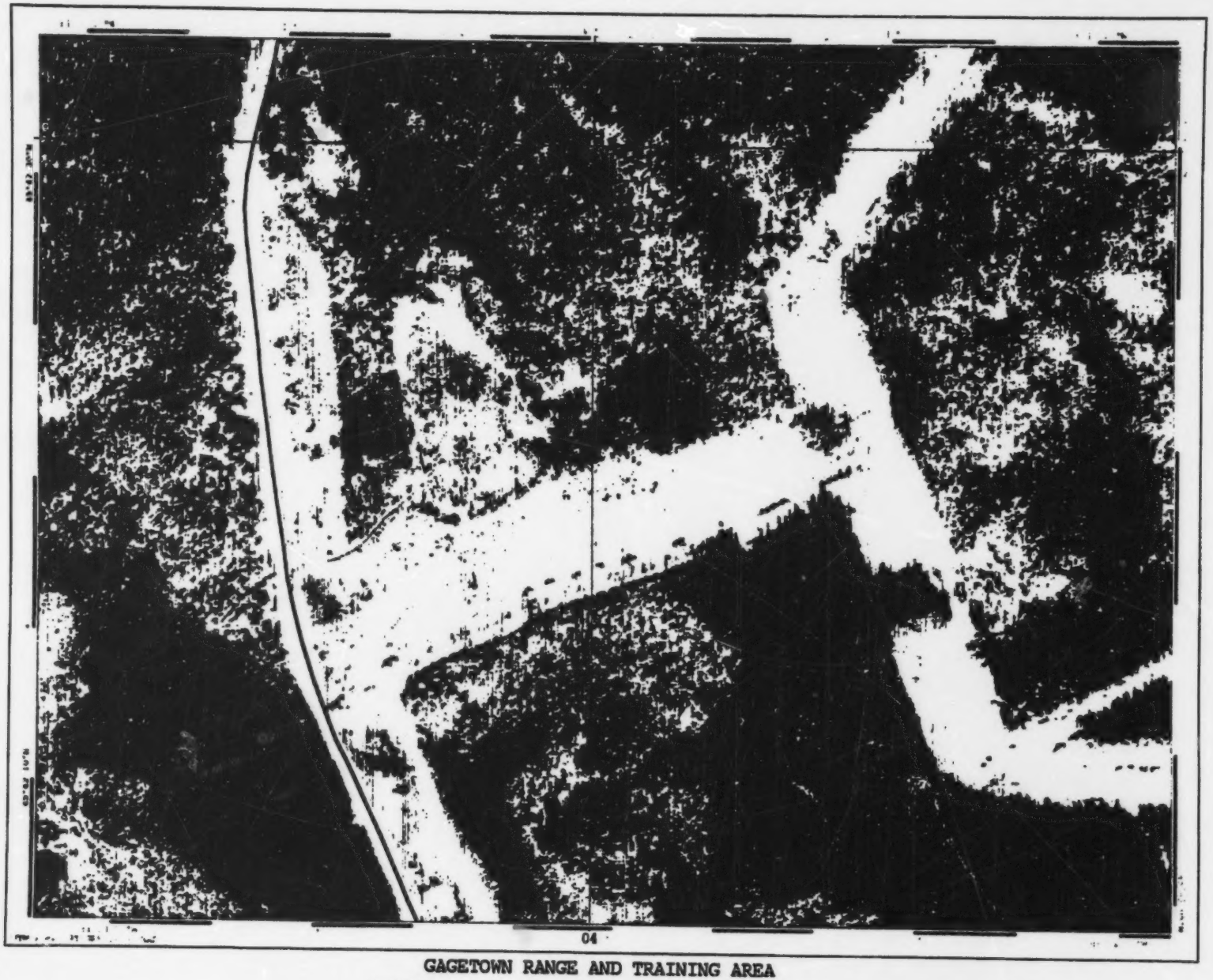
97-2488

97-2489

GAGETOWN RANGE AND TRAINING AREA

Aerial Photos Nov 95 (Prepared by Halia Sushko G3 GIS)

1:10 000 Scale



GAGETOWN RANGE AND TRAINING AREA

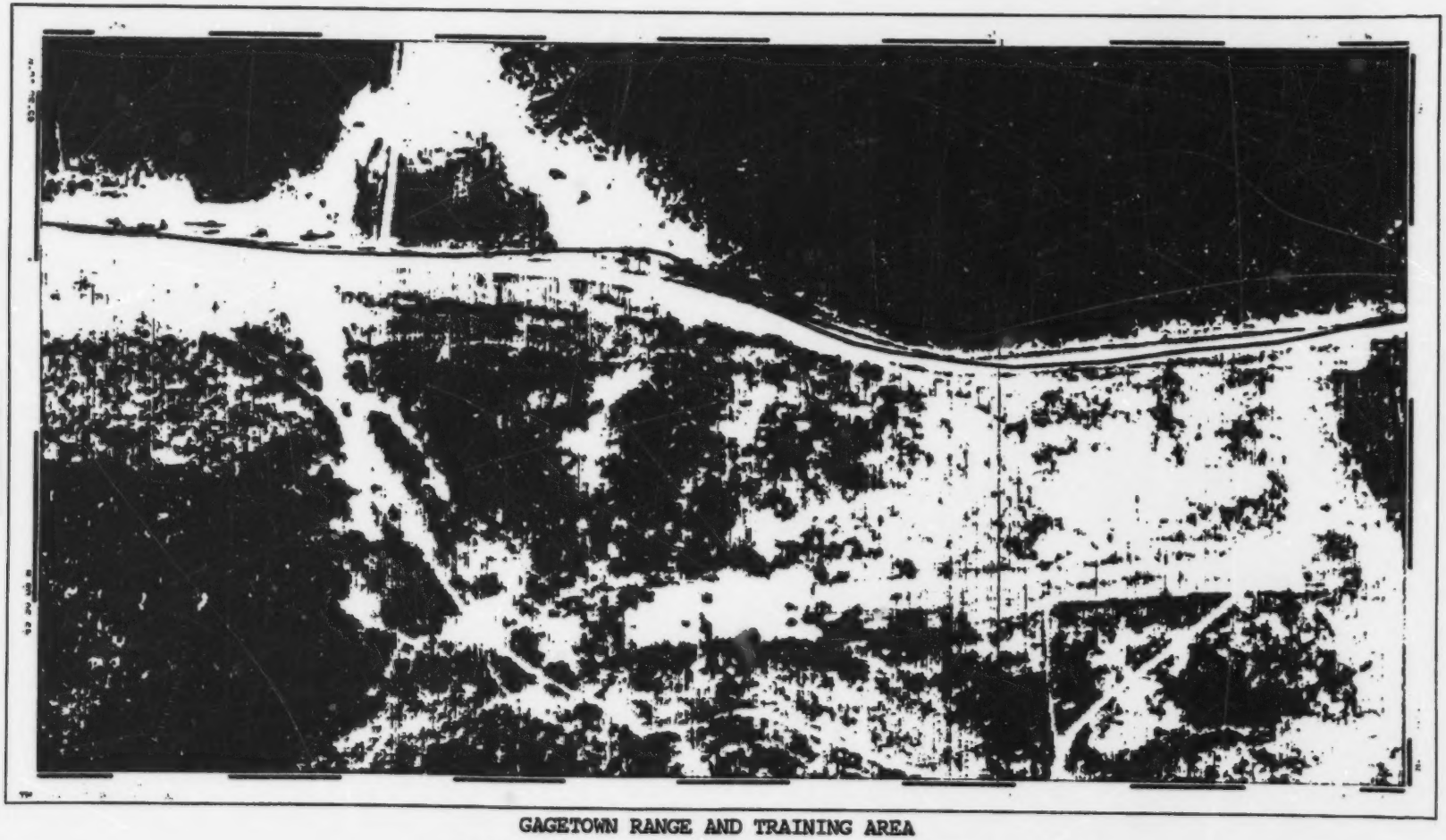
Aerial Photos Nov 95 (Prepared by Halia Sushko G3 GIS)

1:5 000 Scale

Metres 100 0 100 200 300 400

Yards 100 0 100 200 300 400

97-2491



GAGETOWN RANGE AND TRAINING AREA

Aerial Photos Nov 95 (Prepared by Halia Sushko G3 GIS)

1:5 000 Scale

Metres 100 0 100 200 300 400

Yards 100 0 100 200 300 400

GAGETOWN RANGE AND TRAINING AREA

Aerial Photos Nov 95 (Prepared by Halia Sushko G3 GIS)

1:5 000 Scale

Metres 100 0 100 200 300 400 500 600 700

Yards 100 0 100 200 300 400 500 600 700

97-2492

227

GAGETOWN RANGE AND TRAINING AREA

Aerial Photos Nov 95 (Prepared by Halia Sushko G3 GIS)

1:20 000 Scale

Kilometres 1 0 1 2

Miles 1 0 1

97-2493

97-2494

97-2495

GAGETOWN RANGE AND TRAINING AREA

Aerial Photos Nov 95 (Prepared by Halia Sushko G3 GIS)

1:5 000 Scale

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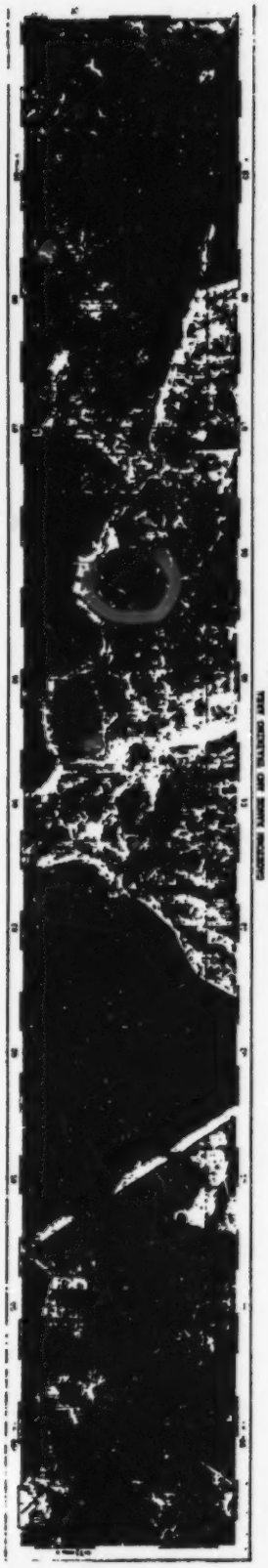
Yards 100 0 100 200 300 400 500 600 700

97-2496

97-2497

97-2498



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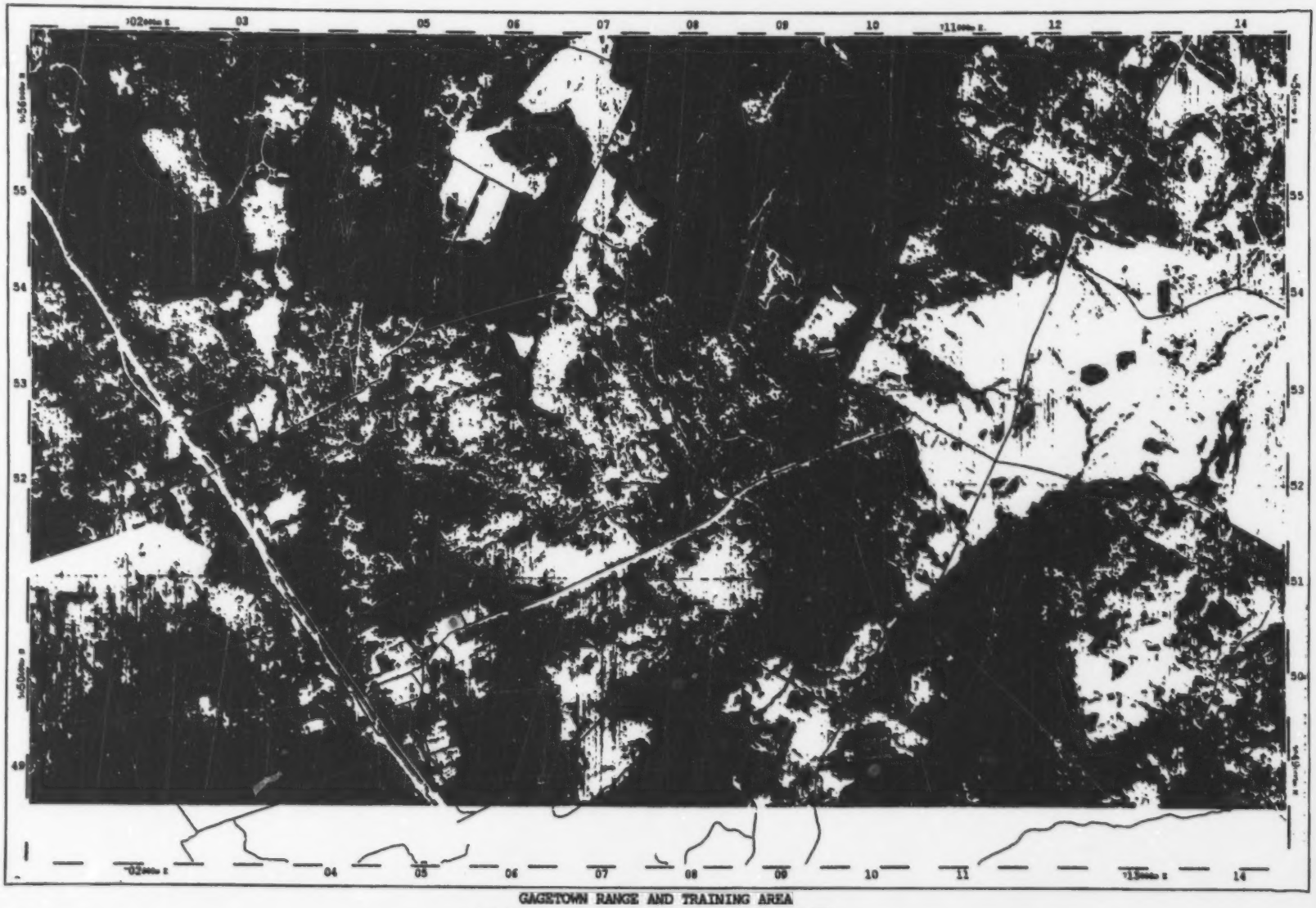
CAGETOWN RANGE AND TRAINING AREA
Aerial Photos Nov 95 (Prepared by Halls Dunkin 05 023)
1:12 000 Scale

97-2500



GAGETOWN RANGE AND TRAINING AREA

Aerial Photos Nov 95 (Prepared by Halia Sushko GS GIS)

1:20 000 Scale

GAGETOWN RANGE AND TRAINING AREA

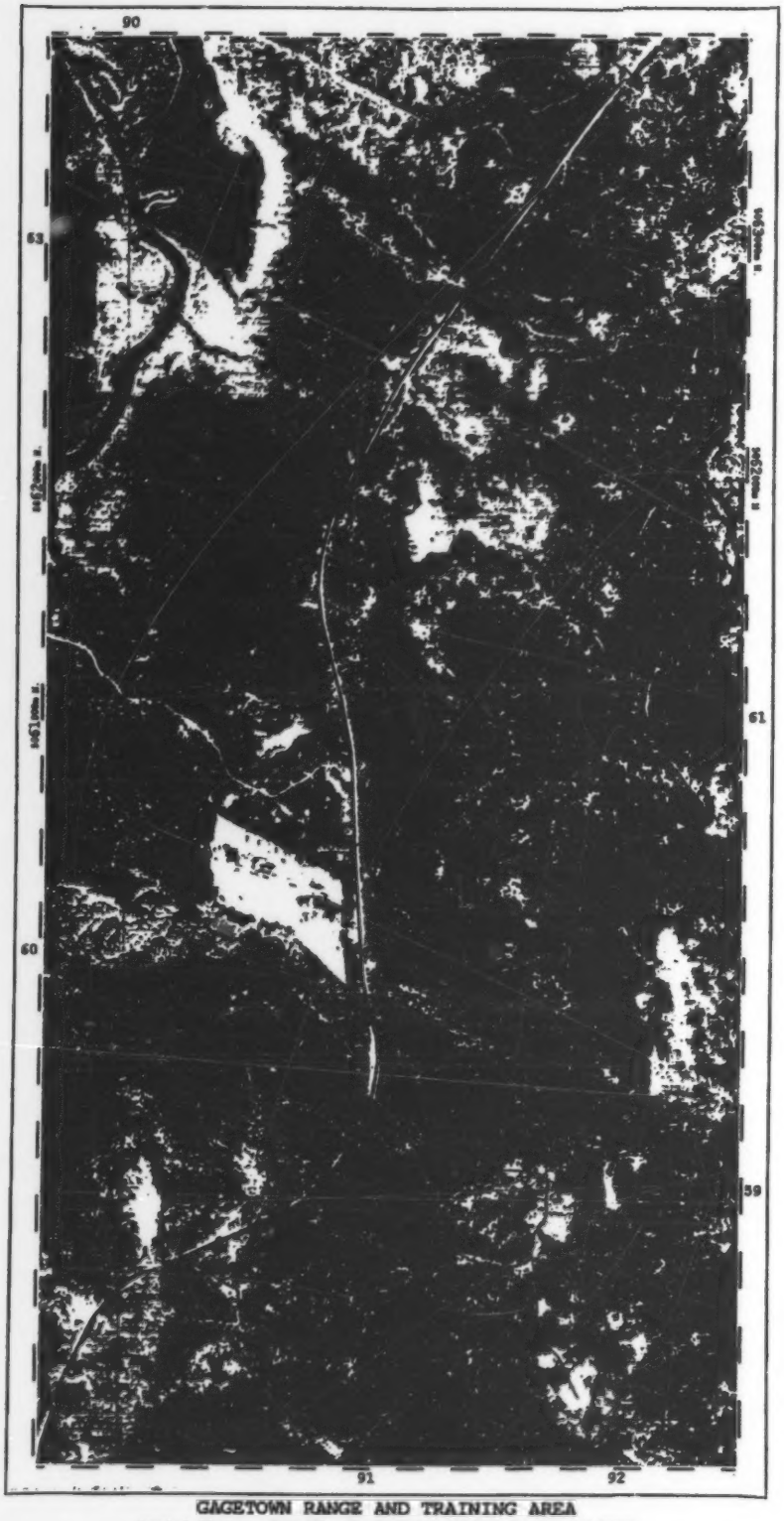
Aerial Photos Nov 95 (Prepared by Halia Sushko G3 GIS)

1:5 000 Scale

Metres 100 0 100 200 300 400 500 600 700

Yards 100 0 100 200 300 400 500 600 700

97-2502

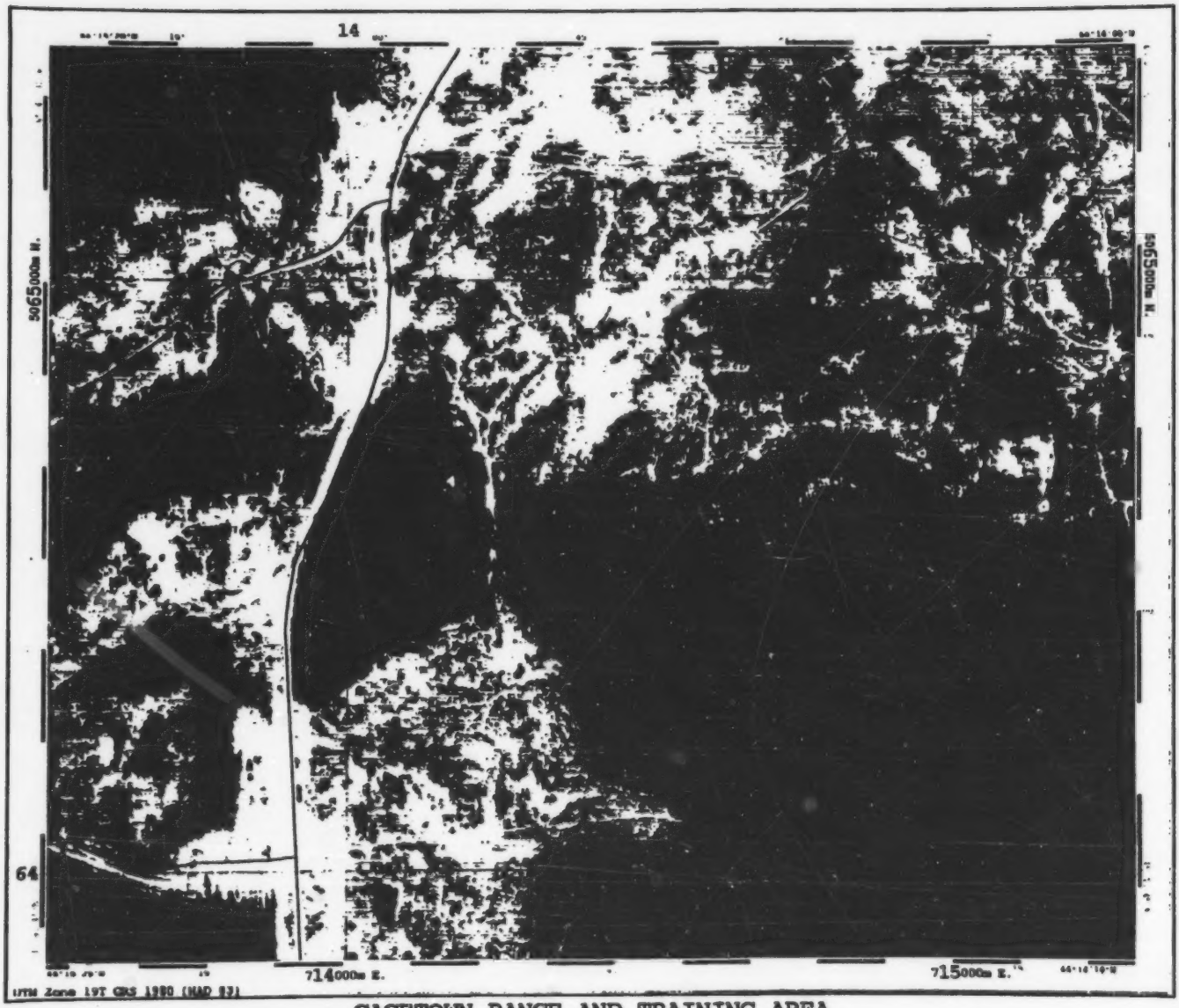


GAGETOWN RANGE AND TRAINING AREA

Aerial Photos Nov 95 (Prepared by Halia Sushko G3 GIS)

1:10 000 Scale

97-2503



GAGETOWN RANGE AND TRAINING AREA

Aerial Photos Nov 95 (Prepared by Halia Sushko G3 GIS)

1:5 000 Scale

Metres 100 0 100 200 300 400 500 600 700

Yards 100 0 100 200 300 400 500 600 700

97-2504

97-2505

QUARRY (Lauvina Wood)
Prepared by Hale Rankin GS GIS
1:2 000 Scale

97-2506

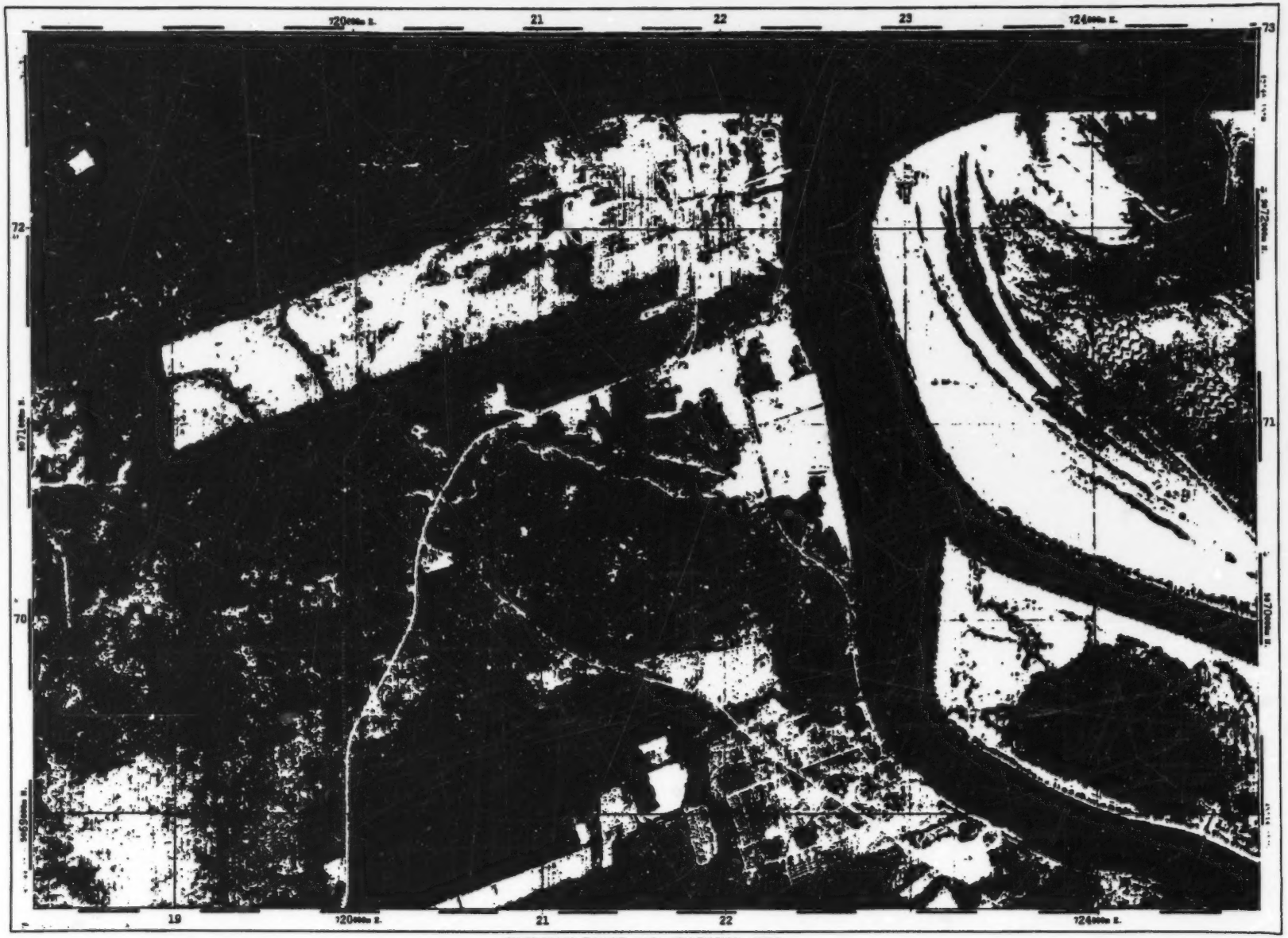
GAGETOWN RANGE AND TRAINING AREA
Aerial Photos Nov 95 (Prepared by Base Gagetown GIS Unit)

CANTONMENT RANGE AND TRAINING AREA

97-2508

GAGETOWN RANGE AND TRAINING AREA
Aerial Photos Nov 96 (Prepared by Mills Geobase CO #22)

97-2510



GAGETOWN RANGE AND TRAINING AREA

Aerial Photos Nov 95 (Prepared by Halia Sushko G3 GIS)

1:30 000 Scale

Kilometres 1 0 1

Miles 1 0 1

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Also, marsh and wetland information from regions surrounding the base, was provided to us by Andrew MacInnis, Ducks Unlimited Canada, 752 Union St., Fredericton, NB.

LIST OF ACRONYMS AND ABBREVIATIONS

APC	Armoured Personnel Carrier
CT	Commercially Thinned forest stand
DREO	Defence Research Establishment Ottawa
GPS	Geographical Positioning System
LSVW	Light Stationary Vehicle Wheeled
M109	long barrel gun
M113	track vehicle
M114	Howitzer Gun
MLVW	Medium Light Vehicle Wheeled
MIT	Moving Inventory Target
MVT	Moving Vehicle Target
N/A	Not applicable
RH	Relative Humidity
SIT	Stationary Inventory Target
SLC	Single Look Complex image product
SVT	Stationary Vehicle Target

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4. AUTHORS (Last name, first name, middle initial)

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Technical Report providing ground truthed information for multi-temporal SAR data set. Also provides preliminary backscatter analysis of environmental and target clutter.

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A collection of Radarsat images over CFB Gagetown, NB has been collected since mid-1996 for the purposes of studying multi-temporal backscatter behaviour. This technical report is the first of two written reports. In this report, ground truthing results and preliminary analysis results are documented while in the next report, a more detailed analysis will be presented.

The ground truthing documented here was provided by two sources; CFB Gagetown and DREO personnel. CFB Gagetown provided ground truthing of the base while many of the image acquisitions occurred. DREO conducted extensive ground truthing for stationary sites on the base in the fall of 1997.

The analysis of this data will concentrate on clutter and target backscatter behaviour with reference to the statistical and physical characteristics. In this report, a preliminary analysisof two images is also presented. These images were chosen so that two extreme environmental conditions are represented. One image is from the summer when the foliage is well developed while the other image is from the spring when snow is still on the ground and some thawing processes have commenced.

Most of the clutter results determined for this report correspond very well with the clutter backscatter coefficients found in the literature. The variability of backscatter with seasons and precipitation was found to have a large dynamic range for some clutter types or scenarios.

In many cases, it was impossible to distinguish targets from the clutter, particularly since the resolution cell of Radarsat images is often smaller than most targets. For future studies like this, it is advised that the data be accurately geo-referenced in order to evaluate the backscatter from small targets.

The environmental backscatter results and variability were often similar to other values found in the scientific literature. Target backscatter results found here are not reliable because it was difficult to identify most land targets.

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Synthetic Aperture Radar (SAR), backscatter coefficient, radar cross section, environment and target clutter, multi-temporal

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